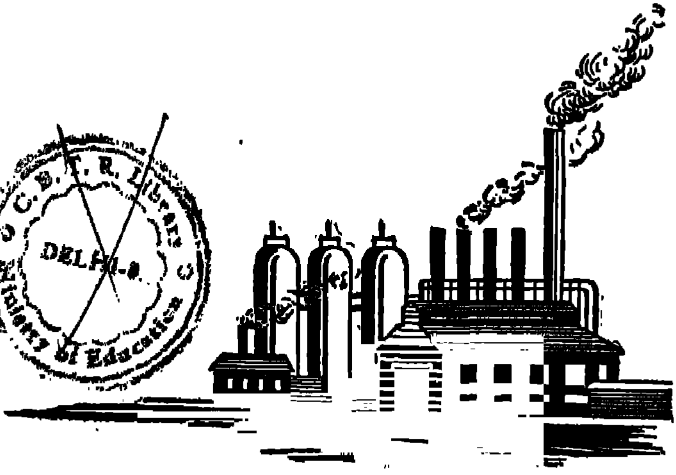
INVENTORS BEHIND THE INVENTOR

also by Roger Burlingame

WHITTLING BOY

INVENTORS
Behind the
INVENTOR

by Roger Burlingame



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INVENTORS BEHIND THE INVENTOR

I

HEROES AND GHOSTS

I

WHEN YOU SAY THE WORD *inventor* TO MOST AMERICANS, A lot of pictures jump suddenly into their minds. They see Samuel Morse with his great white beard and his chest covered with medals standing by a telegraph key, ticking off the message "What Hath God Wrought." They see Robert Fulton watching his awkward little steamboat with great clouds of black smoke pouring out of it, crawling up the Hudson. They see Eli Whitney grinding away at his cotton gin and they see Edison standing stiffly by a large incandescent bulb, considerably bored by the crowd of admirers round him. Some Americans even see Henry Ford watching his cars roll twenty seconds apart off his assembly line at River Rouge.

These are all pictures of popular American heroes. There is a regular parade of them before your mind's eye whenever anyone says the word *inventor*. Then suddenly, when you begin to think about the most modern things of all—common things that you use every day—the parade disappears and there are no more heroes.

Who invented the dial on your telephone and the machine switching behind it? Who invented the fluid drive or cellophane or Flit or the oil burner or fluorescent lights or nylon? Who invented technicolor or the thousand tricks of the movies, like transparencies, miniature sets or sound effects? Who invented certain things you rarely see but know are there doing important jobs, like bombsights, submarine detectors, wave filters, the coaxial cable?

The best you can say is that General Motors invented this, or that another device came out of the Bell Laboratories, but where is the hero? Where is the man with the decorations on his chest receiving the cheers of the crowd? What statues will be put up to commemorate the inventor of light-bending lucite, or the radio beam that guides flyers through the fog, or the self-sealing gas tank that saves the fighting planes?

The heroes are gone. They belong to the past. Today, with all the thousands of inventions that come every year to make our lives simpler—or more complicated—only a few names stand out. Exceptionally well-informed people can tell you that Leo Baekeland had much to do with devising the plastic Bakelite, that Edwin Armstrong produced a revolution in the technic of broadcasting or that many gadgets on automobiles are, rightly or wrongly, associated with the name of Charles Kettering, or that polaroid came, largely, out of the brain of Edward Land. But these men are not cheered in the streets or carried on people's shoulders or showered with medals. If you talk to them, most of them will hasten to explain that they had plenty of assistance. No—the old-time inventor-hero is no longer there when you go to look for him.

Yet people are still inventing. Such things as radar and penicillin do not just drop from the sky as frogs are sometimes supposed to do in a heavy rainstorm. Men and women invent these things, as they always did. Why are they nameless? Why are there no heroes to decorate, to dine and wine and make speeches about in this history of invention that we are making today?

That is the question this book will attempt to answer.

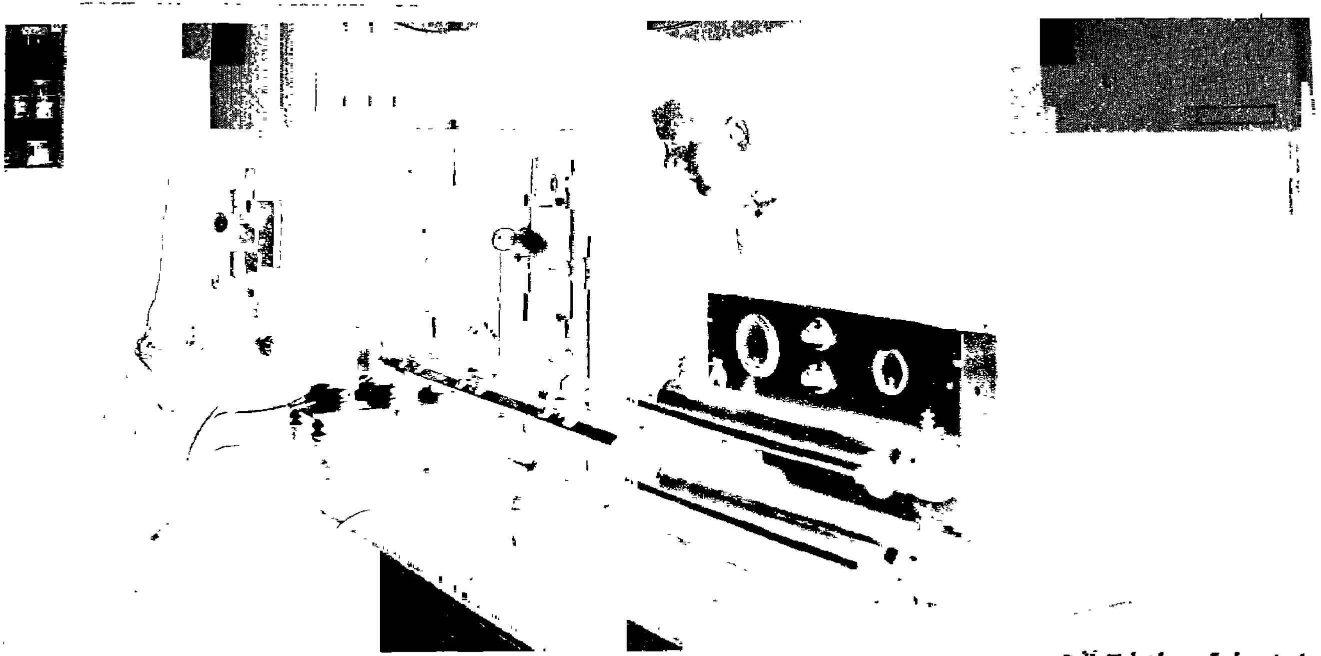
2

You will find, if you walk back slowly through the history of invention in America, a thing that may surprise you. It is certain to surprise you if you were brought up as so many of us were in the old legend—the hero myth. If you will let your eyes get used to the terrific limelight that is thrown upon such figures as Morse and Fulton and Edison, you will gradually begin to see ghosts standing in the dark behind them. Sometimes there is a great army of these ghosts stretching back as far as you can see into the ancient mists of time. Again the shadows seem to be still living men; men who were boys, perhaps, when some recent hero like Edison was old—men who are old, now, themselves.

If you will now shift your attention from the heroes to the ghosts, you will find some of them so important that the hero could have done nothing without them. There was Joseph Henry who had a practical electromagnetic telegraph in working order while Samuel Morse was still painting portraits. There was John Fitch whose steamboat was carrying passengers on regular trips while Robert Fulton was still in France studying canals and submarine mines. There were several people whose incandescent lamps glowed before Edison's, and several others in England, France and America who were projecting pictures on a screen while Edison was still tinkering with a nickel-in-the-slot "peep show." And where would the movie people have been without the invention of celluloid by the Hyatt Brothers, or Hannibal Goodwin's and Henry Reichenbach's formulas for nitro-cellulose film?

Yet all these people, and hundreds of others, stand outside the circle of the spotlight. It is not easy to find them. It seems as if the great American public, intent on its hero worship, were trying to keep you from seeing them. For years the public wanted to be able to point to one man and say, "He did it. He did it alone. He saw the idea in a vision and worked at it secretly in an attic or a cellar until the entire invention was finished." Americans liked this kind of picture and they did not want it obscured or confused. The result is that the true background of American invention is more obscured today—more distorted and confused—than any other aspect of our history.

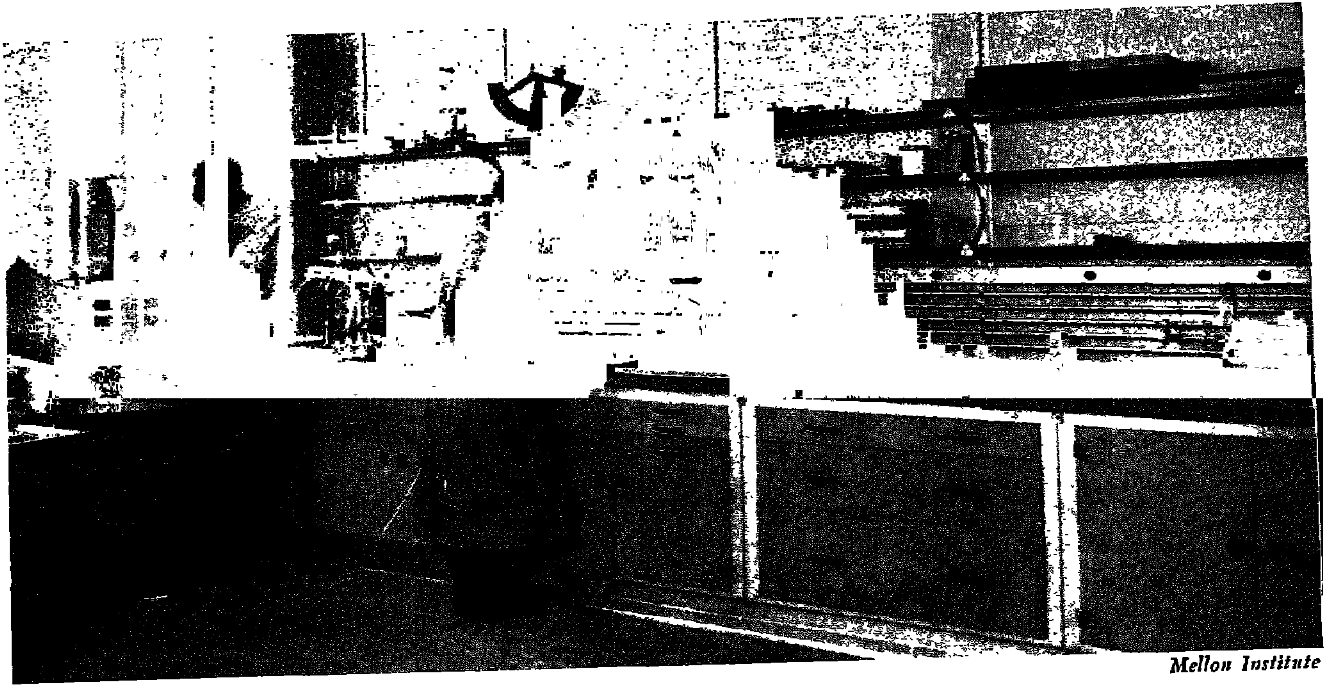
It was true that many of these inventor-heroes worked secretly. Quite naturally they wanted a patent and some reward for their work before someone else stole their ideas. They worked secretly, but they did not work alone. They had valuable assistants who, sometimes, were greater inventors than they. The assistants, of course, were bound to secrecy and in secrecy many of them remained to the end of their lives even after the hero got his patent and made his fortune. Some of them died unknown and poor, either because they did not push their claims, or because the public refused to recognize their



Bell Telephone Laboratories

BEHIND THE TELEPHONE

Endless invention and research go on in the Bell Telephone Laboratories. Here is spectography, a method of chemical analysis of materials used in the telephone system. The material is heated to incandescence in an electric arc and the light is split into a spectrum by a quartz prism. The lines of the spectrum recorded in a photograph can be identified by comparison with the lines of known spectra.



Mellon Institute

RESEARCH ON COMMODITY STANDARDS IN MELLON INSTITUTE

Invention, for the most part, has moved out of the lonely garret into the carefully, expensively equipped industrial research laboratory. A "fellow" of the Mellon Institute of Pittsburgh is given a workshop like this in which to solve special technical problems.

claims. So they became ghosts behind the heroes.

It is easy to feel sorry for the ghosts. When you see people devoting their whole lives to a purpose and find that not only did they get no credit, fame or money, but their names were even forgotten in the history books, it makes you want to tell others about them. But then you begin to see that even behind them stand still more ghosts until, finally, you give up believing that any one man ever made any one whole invention alone.

3

As we come into the twentieth century, this fact becomes more and more obvious until now, as we approach the mid-way mark of that century, even the hero-worshiping public has found that it must give up pulling lonely geniuses out of garrets and setting them up as headliners of invention.

The thing that made it obvious that such persons could no longer do large jobs themselves was the immense enlargement and complication of the sciences. Simple old theories began to break up into dozens of new divisions, as when, for instance, the atom of matter, supposed to be the smallest particle, was found to contain a whole solar system of its own with ions, protons, neutrons and other strange new bits and pieces going about their business inside it. The study of such things took the whole of a man's time. The simple electrician who for years had contented himself with the alibi that "electricity is a mysterious force—we use it but we don't know what it is," suddenly found himself with several things like electrons which electricity might be, and he found, what was more, that he couldn't even use it in advanced ways without the new knowledge. So he had to call in the physicist or the chemist or whoever was devoting his life to atoms to help him.

In the same way, the science of relativity suddenly added a fourth dimension to our solid old length-breadth-and-thickness world—a dimension which seemed to be distorting the other three. The fourth dimension jumped like a flea when ordinary people tried to put their fingers on it, and it took specialists with trained minds and some eighteen hours a day of time to learn to catch it and tame it. So inventors had to consult these specialists too. And when sciences began to add new departments—when metallurgy added metallography, chemistry added organic synthesis and radioactivity, electricity added radio waves and on so—there came to be plenty of specialists to consult.

The public began to bog down on its inventor-worship about the time that the last of the old-line heroes, Marconi, was "inventing" wireless communication.

Probably the general public in America never got so widely and genuinely excited over any application of science, except perhaps aviation, as they did over communication by radio waves. They did not take this for granted as they had other inventions, but literally millions of people began to investigate it for themselves. Now it takes very little investigation in radio history to find that Marconi merely combined knowledge which had been handed him by Hertz, Maxwell, von Helmholtz, Preece, Crookes, Kelvin, Lodge, Heaviside, Branley, Righi, Popoff and many others all the way back to Franklin—and used it in a set of gadgets for extremely practical message-sending.

And then, after Marconi, inventors came so thick and fast to produce radiotelephony and the transmission and amplification of music, political speeches and chewing gum advertisements, that the public could not hope to follow their names even if they had caught them in the first place. In those thrilling days of the beginning of radio—long before broadcasting—amateurs and hobbyists became inventors themselves and they were so fascinated by the endless subject that they even forgot about money and profit. There was, for instance, the great army of nameless boys—people from ten to twenty years old—who worked in woodsheds and barns and such corners of the kitchen as they could borrow from their mothers: worked at little homemade sets that picked up far-off messages, until they too became inventors. A lot of those boys are in laboratories today. They are still nameless as far as fame is concerned and most of them care very little.

It was soon after the first World War that invention came to be called "research" and that inventions were recognized as coming out of industrial research laboratories instead of out of attics and cellars of individual heroes. Edison had started this fashion with his great laboratory at Menlo Park which was sometimes called an "invention factory." This was years before the war. The trouble with it was that the public in those days was so hero-minded that although they could see the laboratory with its hundreds of workers, they still gave Edison himself the full credit for everything that came out of it—even when he had had little or nothing to do with it beyond paying the workers.

Today you will hear the General Electric Company or the Dupont Laboratories criticized for not giving full credit to the men in them who invent things out of which the company makes millions of dollars. It is true, as we shall see, that the progress of invention has been slowed sometimes by too strong a desire for profit. Perhaps it is true that some brilliant research men are underpaid by the corporations they make rich. But if we are talking about individual credit, it is easy to see that, in really complex laboratory work, it is nearly impossible.

Let us suppose, for instance, that the laboratory is run by the government, as many are, and that it is entirely free from any suspicion of profit motive. If the research staff is well balanced —and it must be well balanced to produce good inventions, good machines or processes—it will be impossible to pick out any one man and say, "He did it." The most you can say is, "The team did it. It is a great team so what it invented is a great invention." Invention, in 1947, is with a few exceptions which we shall look at, a matter of teamwork.

4

We have seen football games in which the winning team has been so well balanced that no individual can be given credit for the victory. A good industrial research laboratory of the sort that makes modern inventions is like a well balanced football team.

A football team has a coach who directs or guides its play. Who is the coach or director of the research laboratory? Usually, nowadays, he is the financial manager of the industry which owns the team. He must think primarily of profit for his company. He must think of surprise factors like public demand and sales resistance. Many such coaches have brought spectacular victories to their teams. Others have counseled dirty play, though this practice is less common since the government has been refereeing the games. Occasionally such a coach will lose or deliberately "throw" the game for his team. Many an invention has failed to go over the line because the coach saw too little profit in the touchdown.

This question of the coach or person who directs team invention is an important one. It is a fact that many good inventions have actually been abandoned because the people who controlled them saw no profit in them. In the Patent Office at Washington you will find plenty of patents owned by large corporations—patents of good useful inventions which are just lying there collecting dust. Other inventions have never reached the patent stage because the teams were called off. There was no money in them, no profit, maybe even a loss to the company which manufactured these new machines or processes. Perhaps there would be no public demand for them—they would be hard to sell. Perhaps they could be sold too cheaply and would therefore kill some other product which was highly profitable to the company—or to some other company with which the researching company was financially tied up.

It is not always a bad thing to kill or abandon or delay an invention. A lot of the gadgets that come on the market every year are mere toys and waste our time. Others are dangerous if they come before we are ready for them—cause accidents unless we have laws or police regulations governing their use. Still others—labor-saving machines—throw too many people out of work too suddenly. Such machines as the Rust mechanical cotton-picker are held back for this reason. But who is to decide these questions? Certainly not the coach of a research team who is interested only in profits.

5

This brings us to another kind of inventor who should stand in the background of every invention that is made. In a book about "inventors behind the inventors" he cannot be left out. Sometimes he is hard to find. Sometimes he is not there. Sometimes he comes along late and we see him running to catch up. In this case he is "behind" in the wrong sense—for "behind" in the title of this book means supporting, pushing, helping, not backward or late.

This inventor has been called the Social Inventor to distinguish him from the Technological Inventor. He does not invent machines or technical processes. His concern is with people and society (groups of people), and his job is to invent ways for people to use machines and processes for their welfare and for the general good of the human race.

Much of the misery in the world today is caused by the absence of social inventors. To show what a social inventor is and what he should do, suppose we begin by a few examples of what happens when he is not there, working side by side or ahead of the technological inventor, leading him as well as supporting him.

Because no social inventor had worked out a way for human beings to live in peace and harmony with one another, the airplane came to be used to destroy, instead of to increase the world's production and happiness. Because social inventors were not on the job when the automobile came along, it caused accidents, congested cities, defeated its own speed in traffic jams on the roads. Social inventors are working overtime now on traffic laws and parking tricks, but they are late—"behind" in the wrong sense. Because social inventors have not found useful jobs for men to do which cannot be done by machines, thousands of men become unemployed when a great new technological invention like the automatic strip-mill comes along. Then the running, breathless, late social inventors have to invent devices like relief or unemployment compensation to keep these men from starving. The Germans did it by inventing a war, one of the most backward social inventions in history.

The cheap, mass-produced helicopter, which will land in your back yard or take off from your neighbor's flat roof, may become a reality at any moment. A wonderful invention! But how about parking places, traffic regulation, accident and crime prevention for this new monster coming down everywhere from the skies?

If the helicopter's inventive team had a social inventor for a coach, he would say, "Wait. I don't want you to play that game just yet. Give me a chance, first, to prepare the field, to see what the odds are against you. I want you to win a victory with this invention—a victory for human welfare, for social happiness."

Examples of social inventions are democracy, the city, the library, the hospital, the park, the fire department, baseball, the army and the club. Most of these make use of technological inventions. Some, like the theater or the highway commission, the navy or a power-and-conservation development such as the

Tennessee Valley Authority, are close combinations of the two kinds of invention.

We shall have a better civilization as soon as we can get social inventors and technological inventors to work together. No laboratory team should ever start an invention without first going into a huddle with a social inventor and getting his go-ahead signal. It will be a far surer start for the victory of an invention than any order from a coach who thinks only in terms of profit.

In all this exploration, then, the social inventor should always be somewhere near us, so that we can consult him. If he is not, we will ask for an explanation of his absence.

At the start, he will not be hard to find. The first real American inventor, the inventor behind them all, was a social inventor and technological inventor combined. Benjamin Franklin is visible in almost every background. He thought at least a hundred years ahead of his time and some of his ideas were so far advanced that even today we are not yet ready for them. He made the blueprint of the America we know. He drew the plans for its statesmanship, its foreign relations and, to some extent, even for its social organization. But he also laid the basis for the intelligent study of electricity all over the world, and some of the very devices he invented or improved two hundred years ago are in use today in our radio techniques.

Franklin was too rare a genius ever to be forgotten. Unlike many of the inventors we shall meet, Franklin was a hero in his own right and in his own time. His patents were not disputed because he patented nothing. What he invented, he gave to the world for the benefit of humanity. He asked no credit nor profit, demanded no honors. Perhaps that is one reason why his fame has lasted so long.

But he belongs in this book because so little of the modern history of invention in America could have been written without him.

2

BEHIND THEM ALL

1

AT DAWN, ON THE HOT MORNINGS OF THE SUMMER OF 1721 in Boston, a dozen boys would gather on one of the harbor wharves.

Among the coils of marlined rope, surrounded by the towering poops of ships and the forests of masts and rigging above them, as the sun came over the harbor-rim from the East, they would take off their clothes and lie about for a while, each of them waiting for someone else to take the first plunge. Suddenly another boy would join them; he waited for no one, he had no time to lose. Silence used to come over the group as he pulled himself up to the deck of a schooner and moved out on the sprit.

He was younger than they, but bigger; his build was straight and sturdy, his muscles tough but smooth. His feet moved to find the perfect balance on the difficult up-pointed sprit; his arms were raised for the dive.

If only a modern cameraman could have been there to snap his fast shutter—and again one second later, catching the lad in mid-air—we could set these pictures one on each side of our stuffy old portrait of the preaching, copybook moralist whom five generations of young Americans have tried so hard to revere—the "thrifty," the "industrious" Benjamin Franklin!

There was nothing cautious or didactic or holier-than-thou about the boy on the bowsprit. Already at fifteen, he had the restless devil in his blood that would carry him over the world, and bring the peoples of far, strange nations to his feet; that would turn a whole scheme of society upside down and bring freedom to America. Already, he had that unquenchable curiosity that later would lead him to catch the lightning out of the sky and confine it in a glass jar on a table; that would reach a century into the future until he could draw a picture of our modern world with its communications, its education, its statesmanship, its health, its democracy, its understanding of science. And already at fifteen, this bold, quick-witted, sharp-tongued printer's apprentice had scared old Boston out of its complacent slumbers: he had attacked its sacred preachers, its sacred Harvard College, its sacred colonial government and with his own fingers set the type of his fearless writings.

Moving with an even, efficient stroke over the water, a mile out into Boston harbor, he never stopped thinking. There in the clean, cold element that he had mastered until it was home to him, he planned the day of work. Into it he fitted more jobs than any of his friends on the wharf could have worked into a week of hard effort. Ben invented new ways of doing everything he did. He found short cuts in typesetting, presswork, going to and from his job—even eating and sleeping—that saved him, in the aggregate, months of time. When work tired him, he invented ways to toughen himself against fatigue.

Swimming back to the dock, he forgot the day's job ahead. Now he dreamed of escape in the time when Boston would grow too small for him. The boy knew he could not stick it here forever. His brother, for whom he worked—bound by a hard contract—could never give him a wide enough field for his energies. The little newspaper his brother printed was far too narrow for a mind that was already seeing world horizons. So Ben, swimming back to work, felt the devil jump in him—the devil that had sent one of his brothers away to sea, the devil that would never conform either to a hired man's job in a printing shop or to the little workroom where his father made tallow candles. He climbed back up the wharf, just as his friends, heavy and sleepy, were lowering themselves into the water. He laughed at them, dressed and went on.

2

Boston became too small for Benjamin Franklin when he was seventeen. By that time he had read every book he could get his hands on, taught himself geography and arithmetic, which he had failed in school, learned to feed himself on one quarter the amount his brother had budgeted for his keep and got his brother into jail for his unsigned editorial writings. He had proved to his family and friends that a growing man can live healthily on a vegetable diet without liquor, on six or seven hours of sleep, taking baths regularly—an unheard of thing in a Boston winter.

So Boston, at the same time that it began to cramp Ben's desires, began to be uncomfortable in other ways. He guessed he had done his brother enough harm to justify breaking his contract. On a little sloop, then, which was the best way of traveling long distances in those days, he escaped at night. It was a wet, cold and dangerous journey. He landed in New York, could find no job and pushed on to Philadelphia. So started the career of one of the three or four greatest men who ever lived in America.

His boyhood was hardly the kind a moralist would hold up as an example of great virtue. In the autobiography which he wrote more than half a century later, he has very little to say about this time. A guess, from what he doesn't say, is that if he had not been so constantly busy, he would have been in trouble much of the time. His curiosity was great enough to make him try everything. But one fact is certain about Franklin: he never burned his fingers twice in the same fire. When he had learned a lesson, he knew it completely.

It was this curiosity that kept the tallow candles alight past midnight in his room. Every question that rose in his mind tormented him till he had answered it. If the answer was in a book, nothing would stop him from getting it. There were no circulating libraries then. Franklin later invented this useful device. He would smile his way into a bookstore and stay there till he was thrown out. He was rarely thrown out because he amused the booksellers too much. Ben would tell a story or start an argument when the salesman told him it was time to go. If the answer he sought was in someone's mind, he would probe that mind till he got the answer. That was the way of this tenacious, insatiable, restless, exasperating, charming lad who turned up in Philadelphia in the spring of 1723—wet, dirty, hungry, without money, without a job, with nothing but his wit between himself and starvation.

People stared at his water-soaked breeches, his shapeless coat. Philadelphia was a respectable place. But when he spoke, they forgot his clothes. They could not send him away. "You have no work for me?" he would say. "Good-bye, then." "Wait a minute. Don't go yet." They kept him to hear him talk. They fed him and listened to him. They sent him to their friends.

He was not long in finding work. He was too useful to be kept idle. The printer who took him on to set type found that he could also rebuild presses, keep accounts, bring in business, write printable articles, and save his boss time and money. A printer in those days was an important man in the community and Ben, with the remarkable education he had given himself, soon became more important than his employer. So Philadelphia, too, became too small for him.

By the time he was twenty-one he had spent two years in London, earning his way by giving lessons in swimming, working in printers' shops, writing, publishing pamphlets on religion, philosophy, even politics; making friends, talking, arguing, going to plays, watching London night-life, absorbing the new science that, in those exciting years, was awakening England to the future. For Isaac Newton was there writing his startling laws of physics, Abraham Darby had discovered the use of coke in smelting iron and Thomas Newcomen's first practical steam engine was pumping in the coal mines. Newton died before Ben could see him but he saw and talked with Newton's editor, Pemberton, who started him itching for scientific knowledge.

But in two years of London, Ben learned that Philadelphia was not too small and that America was very large. London, for all its bigness, had not the wide horizons of opportunity, the vast empty spaces beyond it, of the new world he had left. It had not the raw material for the mind of a genius to work with. London was too finished, too polished, too limited by old customs for a boy of Ben's fresh energy.

But London had taught him, too, that people were more important than books; more important than science or machines or printing presses or philosophy or business or money. It was this knowledge that made him a social inventor and a statesman, and the friendships of these young days traced a path for his return to Europe—for the great pilgrimages of his later years when he would carry the message of freedom and the light of science to the whole of the civilized world.

So Ben came back to Philadelphia—a mature man at the age when most of us are beginning to think about our first job.

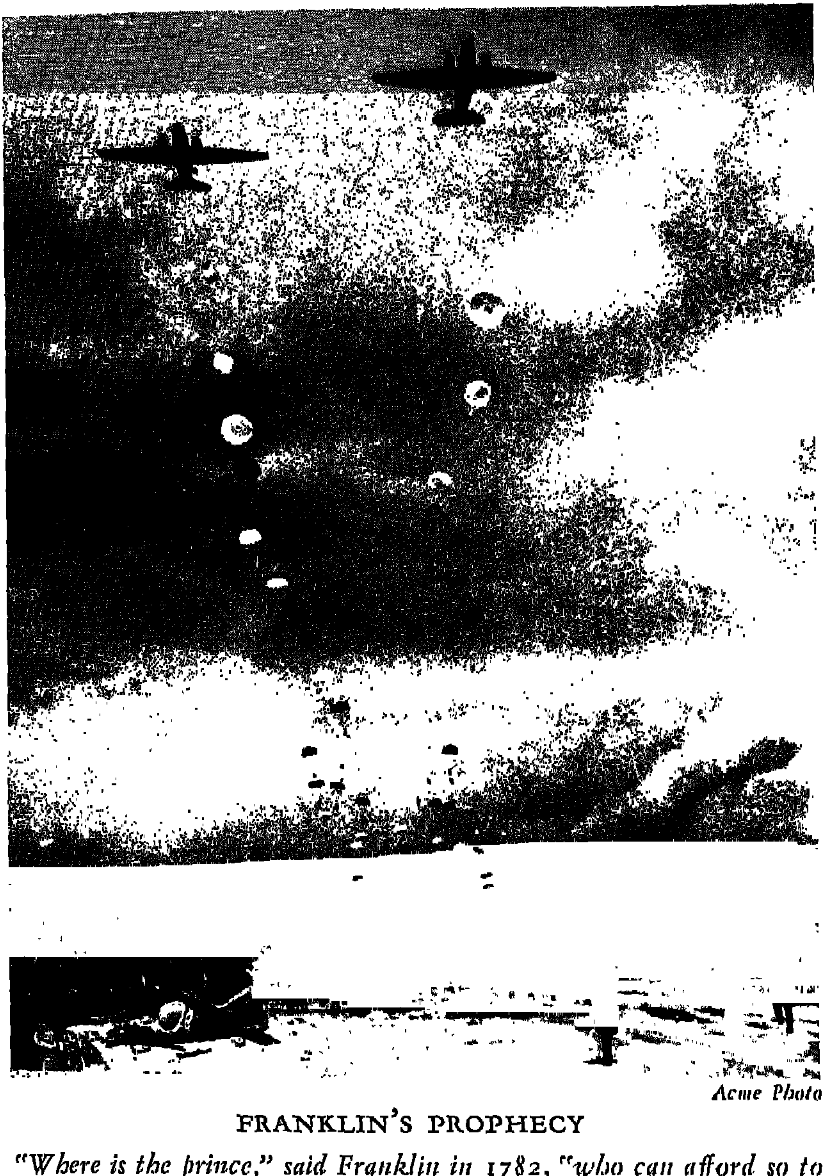
3

The proverb, "a jack-of-all-trades is master of none," is all very well in an age of specialization. It is true enough now when it takes a dozen men to assemble an automobile spring; when one man on an assembly line puts a nut on a bolt and another tightens it. But in Franklin's day, one man built a whole musket, spinning wheel, ox-cart, ship or flour mill with only boy apprentices to help him. Farmers made their own barns, furniture, knives, plates, spoons, shoes, farm implements in addition to doing their farm work, and their wives and daughters made their clothes.

Franklin broke that proverb wide open. He was not only a jack-of-all-trades, but he was master of them all. During his long life, he was a printer, journalist, columnist, salesman, advertising man, promoter, civic organizer, fireman, postmaster, military architect, diplomat and statesman; a scientific discoverer, an innovator in navigation, transport, hygiene, sanitation, city planning, street-lighting, paving and cleaning, hospitalization and higher education. He was a humorist, a political agitator, a clubman, a meteorologist, a student of medicine and an athlete. But first, last and always, he was an inventor. He was the first American inventor worthy of the name.

We are accustomed to think of the colonial Yankees as ingenious, inventive people. After freedom came, Yankees startled the world with their inventions. But in colonial days, they were less inventive than Europeans. Even the jack-of-all-trades farmers copied English models. The best tools, the best of what few machines there were came from England. This was natural. The colonies were English provinces. England's reason for holding these colonies was that they could supply her with raw materials and afterwards buy the goods she manufactured from those materials. Her aim was to keep the colonies in subjection by buying from them at low prices and selling to them at high prices. So if Americans started to manufacture things on their own, England stopped it.

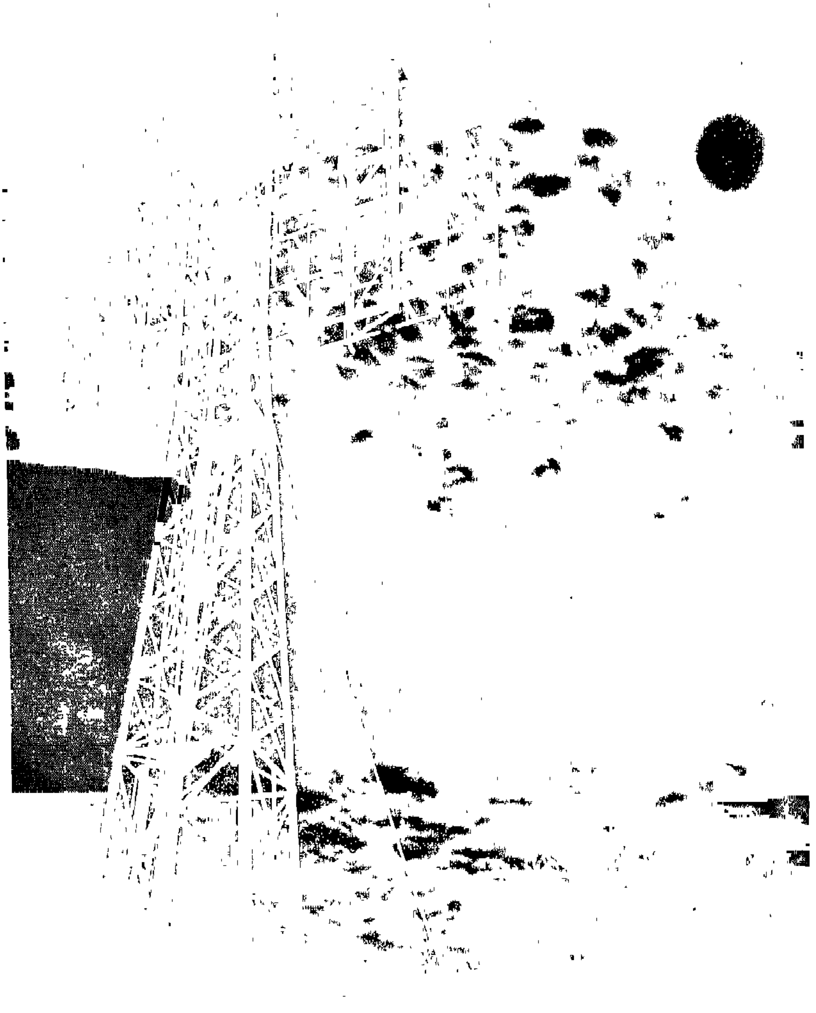
Franklin was born into a dark age in America. Boston was a crowded and dirty town; its people lived in a strait-jacket of religious intolerance. New York was corrupt, with great wealth and great poverty, a haunt of thieves and pirates. Philadelphia was larger, cleaner, more tolerant, but it was smug, snobbish and mean; its streets were unpaved, unlighted and unpoliced. The whole country was afraid of Indians and of the French to



Acme Photo

FRANKLIN'S PROPHECY

"Where is the prince," said Franklin in 1782, "who can afford so to cover his country with troops as that ten thousand men descending from the clouds might not in many places do an infinite deal of mischief before a force could be brought together to repel them." Certainly not the emperor Hirohito of Japan whose armies a century and a half later met these American paratroopers.



Press Association, Inc.

FROM FRANKLIN TO RADAR

Franklin's observations on his experiments with the Leyden jar guided later scientists in the research which led to the discovery of the radio waves. The photograph shows an antenna used by the Army Signal Corps to make radar contact with the moon.

the north. Thousands of people were illiterate, superstitious, believing in magic and the "wrath of God"; there was little sanitation and smallpox and other plagues ran riot along with the rats and pigs in the streets. There were few roads and there was almost no communication except by sea. Houses were cold —heated only by open fires; and they were dark, for whale oil and candles were costly.

Franklin saw through this darkness. Coming back to America in 1727 from the brilliant civilization of London, he saw how it was shutting the people in. He knew, then, of the comedy of life, of the excitement of free talk and unrestricted reading, of the delights of recreation, the fascinations of science, the cruelties of hard religions, the meanness of dirt and poverty. So he invented ways to share this knowledge and make life easier.

In 1730, he invented the subscription circulating library. It began with a few friends and a few shillings. The books piled up. People rushed to read them. A book, in those days, was a treasured thing. The news of Franklin's Philadelphia library spread over the colonies and others started in Boston and New York until, at last, books were available to everyone and what is perhaps the greatest institution in America was well under way in Franklin's lifetime.

Three years later he started *Poor Richard's Almanac*. This came in an age of no magazines. The Almanac was a sort of combined *Reader's Digest, Popular Mechanics, Country Gentleman, Ladies' Home Journal,* cookbook, garden book, medicine book and *Information, Please*. In it were recipes, cures, instructions for the home workshop, information on planting and the weather, changes of the moon; poetry, jokes, anecdotes, wisecracks, advice to lovers, tricks, puzzles, devices to forecast storms and stop the baby from crying. It is hard in these days of radio, tabloids and newsreels to realize what this did for shut-in and lonely people; how it was thumbed and read and earmarked and memorized by every member of the family in the winter firelight of a remote farm or a crowded city slum. Parts of it were crude, parts, perhaps, were vulgar—but it taught people to read and laugh and think, to talk and guess and wonder, to live and love and play and be tolerant to their fellow men; to know what went on in the world, to dream of far places and life beyond the horizon. Men traveled a hundred miles to get a copy of *Poor Richard*. They met other men and talked about it on the way. It was a beginning of democracy in America.

The success of the Almanac led Franklin to think of ways to circulate it. That interested him in the postal service which was a slipshod, haphazard business when he became Philadelphia's postmaster in 1737. The colonial postal service did not extend south of Maryland. The horseback riders in the north were uncertain and rates were fabulous. Most people preferred to entrust their letters to traveling friends.

Franklin extended postal service from the district of Maine to the province of Georgia, laying out the plan of what is now U.S. Route Number One. He regulated deliveries, winter and summer, and reduced the rates so that letters were carried five hundred miles for a little over twenty cents.

In 1742, he invented the "Pennsylvania Fireplace." Imitations of this are now sold as antiques and called "Franklin Stoves."

But Franklin's invention was a hot-air heating system very different from the imitation. It drew fresh cold air into an iron box which was heated by the smoke from the fire which curled round it. The hot air was released through shutters at the side. The fire was not hidden as in a stove but burned brightly as in a fireplace, giving its important light to the room. By distributing the hot air, the fireplace heated not only the space in front of it, but the whole room.

There were no stoves in 1742, except the great Dutch and German affairs made of porcelain, and there were few of these. Beds were heated with warming pans and people took little foot warmers full of hot coals to church. Heat was a rare luxury. Franklin's fireplace was a blessing to all the colonies and it had an immediate success. But Franklin made no money out of it. He refused to patent any invention.

"As we enjoy great advantages from the inventions of others," he wrote, "we should be glad of an opportunity to serve others by any invention of ours; and this we should do freely and generously."

Four years after Franklin's "stove" was invented, he encountered what is perhaps the greatest mystery that has ever puzzled mankind. Such a mystery was meat and drink and life to Franklin's curiosity. He did not solve it—no one has ever fully solved it and possibly no one ever will—but he worked at it until he could state certain facts that others could take hold of and work with. He stated them so clearly that no sensible man could fail to understand, and so he began the true study of a force which is part of every phase and hour, every waking and sleeping second of our life today.

It was his work on this mystery that gave Franklin his fame and his power. His clear statements spread such respect for him over Europe that he was followed by crowds when he walked in the streets of Paris. To simple folk, there was a magic about him that was almost godlike; to scientists he was a prophet, centuries ahead of the world he lived in.

"There goes Ben Franklin who has taken the storm into his hand, who has shown us that lightning is not the wrath of God but a tractable thing which can be led harmless into the ground."

"There is Doctor Franklin who has brought certainty into the guesses of science; who has started a train of thought which generations of experimenters can follow until the mystery at last is solved."

Because of this reverence, Franklin was able, when the time came, to enlist the French in our cause of liberty and bring success to our War of Independence.

But he first met the mystery of electricity in 1746, thirty years before the United States began. He was forty years old when he found it.

4

It was not a new thing. Centuries before, people had noticed that amber, which had been rubbed, drew toward it various particles of matter. All over Europe in the years of Franklin's youth, men had worked up sparks and charges and shocks by friction. Attraction and repulsion had been observed. In London, as it awakened to the new "marvels of science" entertainers went about showing jumping pencils of light, producing explosions, exhibiting glowing tubes like neon lamps to astonished spectators. The entertainers made no attempt to explain why these things happened and even laboratory men gave little satisfaction when they talked about the "invisible fluid."

Franklin saw one of these shows in his home town of Boston in 1746. Doctor Spence had come from England to lecture there. Franklin saw quickly that Spence was only mildly scientific, but the experiments which Spence performed for him privately laid hold on his imagination. He soon improved on them, got his Philadelphia library to buy apparatus and started to work in Philadelphia.

The apparatus looks pretty primitive to us when it is ranged alongside a 160,000 kilowatt generator or a frequency modulation transmission unit. It consisted of a few Leyden jars and a couple of "electrical machines" and many small gadgets—sheets of lead and glass, silk threads, pithballs, wire; the sort of thing we give to children today to show first principles. To Franklin, working in the infancy of electrical science, they were not toys.

Franklin did not shut himself up in a private room as so many experimenters used to do and work in the dead of night lest anyone steal his knowledge. He opened his house to friends and strangers and they crowded it, looking over one another's shoulders at the magic. Occasionally a friend would offer a suggestion. But no one could steal anything, for only one mind in ten million, in those days, was capable of grasping any deep significance from the sparks and reports of what we call static electricity.

An electrical machine was a disk or sphere of glass whirled between pieces of silk. It generated charges. The Leyden jar was a wide-necked bottle half-filled with water, in which these charges were stored by a nail projected from a cork. It had been invented in Holland less than a year before Franklin began his work. It was, in fact, a condenser, and Franklin was the first to call it so.

There were supposed to be two kinds of electricity: vitreous and resinous. One was produced by rubbing glass with silk; the other by rubbing amber or some other hard resin with wool. Each kind repelled its own kind of "electricity" and attracted the other. Franklin, however, exploded this theory, showing that both were the same force, but that one was positive and the other negative, or plus and minus. Because, when a positively charged body was placed near a negatively charged one, the charge would jump from one to the other, he guessed that the negatively charged body had too little electricity, was hungry for more and waiting always to steal some from a body that had more than its share. This is putting the things in simple, human terms, but the greatest scientists do state their discoveries in this way and so make them clear to the world, whereas lesser men obscure them with long words.

This was Franklin's first discovery and some think his greatest. Electrical inventions since his day have depended on this fundamental understanding of positive and negative. While he was making it, he worked out his theory of insulators. He found that the charges stored in the Leyden jar resided in the glass, not in the cork, nail or water. He did this by removing these things, one by one. Always the charge remained. That led him to make the Franklin pane—a sheet of glass between sheets of lead which was a better condenser than the jar. He went on from there to make the Franklin "battery," a series of panes and lead sheets, which was the best of all and held immense charges. When he got to that point he could amuse his friends.

Franklin's knowledge and understanding of electrical effects did not blind him to their spectacular qualities. If his friends wanted a show in the manner of Doctor Spence, Ben would give it to them, but it would be a better one than they could ever get from a showman who staged it as if it were magic. His own description of the plans for a summer electrical "party" reveals the astounding fact that such phenomena as battery ignition, electrocution and wireless conductors were known to him some two centuries before they became commonplaces in our society.

"Chagrined a little," he wrote in 1749, "that we have been hitherto able to produce nothing in this way of use to mankind, and the hot weather coming on, when electrical experiments are not so agreeable, it is proposed to put an end to them for this season, somewhat humorously, in a party of pleasure, on the banks of the Skuylkil. Spirits [alcohol], at the same time, are to be fired by a spark sent from side to side through the river, without any other conductor than the water. . . . A turkey is to be killed for our dinner by the *electrical shock,* and roasted by the *electrical jack* before a fire kindled by the *electrified bottle.*" This party was to be made festive by the "discharge of guns from the *electrical battery.*"

The hot weather may have stopped his friends but it did not stop Franklin. The heat brought thunderstorms and he studied them. He became convinced that lightning and electricity were the same; that clouds were condensers discharging upon the earth just as his electrical machines gave up their charges; that thunder was merely an immense magnification of the sound of his experimental sparks. Franklin made himself a sort of artificial cloud—a pasteboard tube covered with metallic paper like tin foil—and charged it. Holding various objects toward the tube he discharged it. He found that a needle or other sharp-pointed instrument would "draw off the electricity" at a greater distance from the tube than a blunt instrument and with less "stroke and crack."

Characteristically, Franklin asked himself if the knowledge of this power of points might not be of use to mankind. Why not put pointed rods, connected by wire with the ground, on steeples and housetops? Would not these pointed rods draw the electrical fire, and thereby secure people from that "most sudden and terrible mischief"?

Franklin wrote of these things to friends in Europe. We have seen what a way he had of making devoted and loyal friends. He kept always in touch with them, writing them letters packed with information. Letters were precious things in the 1700's being the only means of distant communication. They were not lightly written. The burden and expense of carrying them were considered. You wrote a letter when you had something to say. You wrote no more than was necessary to say it. Franklin's letters were economical of words and for this reason they were direct and clear.

A friend, named Collinson, took Franklin's letter about electricity to the Royal Society of London, the greatest association of scientists in the world. The members laughed and refused to print it. They had their own pet theories and Franklin upset them. But Collinson got the letter printed outside the society. Someone in France discovered it, had it translated into French. When it was published in France it caused immense excitement and experiments were made, to prove the lightning theory, which came at last to the attention of the king. This was in 1752. Franklin was more famous in Europe than in America where there were fewer scientists and interest in scientific discovery was slower.

In that same summer of 1752, Franklin proved his lightning theory with his celebrated kite. Later, he put up a rod on his own house, drew the lightning into the house, and by an ingenious device, caused it to ring bells "to give notice when the rod should be electrified."

It was hard for Franklin to understand his fame, for he was genuinely modest. When he had written to Collinson about the lightning experiments, he had said:

"These thoughts, my dear friend, are many of them crude and hasty; and if I were merely ambitious of acquiring some reputation in philosophy [science] I ought to keep them by me till corrected and improved by time and further experience. But since even short hints and imperfect experiments in any new branch of science, being communicated, have oftentimes a good effect, in exciting the attention of the ingenious to the subject . . . you are at liberty to communicate this paper to whom you please; it being of more importance that knowledge should increase than that your friend be thought an accurate philosopher."

These words express the whole of Franklin's greatness as an inventor and they show why all of mankind took a step forward because he lived in the world.

5

If the ghost of Benjamin Franklin had walked in the beginning of this century, he would have seen his electric battery in the generation of radio waves. He would have seen his belief in particles of electricity justified, after more than a century of denial, in the theory of the electronic stream—proved in the Fleming valve, the audion tube, the regenerative circuit and a dozen other late inventions. He would see millions of people wearing white clothes against the heat, dark ones against the cold—his discovery. He would see millions of pairs of his bifocal glasses giving comfort to hard-worked eyes. He would see improvements on his lightning rods on millions of houses. He would see men and women strengthened by moderate diet, kept healthy by bathing, fresh air, simple clothes, regular exercises. He would be as charmed by our shorts, our topless bathing suits as he would have been disgusted by the concealment of the body by our prudish grandparents, for it was Franklin who invented the sun-and-air bath.

The ghost of Franklin in 1947 would see his library come into its own, bringing free knowledge and amusement to millions of Americans. He would see the University of Pennsylvania, which he founded, grown to dignity and greatness. He would walk on streets lighted, paved, cleaned and protected at the public expense—his innovation in America. He would see daylight-saving time, his own half-humorous suggestion, working for our economy and pleasure.

Most of all, the ghost of Benjamin Franklin would glory in the United States which he first designed in his Plan of Union and whose Declaration of Independence he helped to write, whose Constitution he helped to frame.

More than a ghost of Franklin walks among us today. Smaller replicas of him are in our government, our diplomatic service, the offices of our city planning, our schools, libraries and hospitals, thinking his thoughts, trying to think them the way he did. And there is no American inventor, no laboratory man worth mentioning but has a little of Franklin in him—his essence, his spirit, his pattern.

He is behind them all.

3

BEHIND FULTON

I

"SHE'S A BOAT, SURE ENOUGH; SHE MOVES UPON THE water. . . ."

"But without oar nor sail. What devil is it moves her?"

"Fire and smoke—and philosophy."

"It's irreligious philosophy, invoking the wrath of God."

So talked the crowd on the New York waterfront on a hot August day in 1807, as the *Clermont,* pouring clouds of black smoke from her eighteen-foot stack, moved up the Hudson. Boys, running along the bank, easily outdistanced her. Yet it was a thrilling sight and many voices shouted that it was a miracle.

The men whose jobs were on the waterfront did not join in this chorus of surprise. The chandlers bringing new anchors and ropes out to the hundreds of ships whose sprits stretched high over West Street, the stevedores who rolled the kegs of West Indies sugar and carried the boxes of Canton tea along the wharves, the tavern keepers who refreshed the transient crews, and even many of the crews themselves who had long watched the movement of strange craft in the river and harbor did not call the *Clermont* of Robert Fulton and Robert Livingston a miracle. She was bigger, to be sure, than anything they had seen, and far uglier; she made more noise and more smoke, but a vessel moving without sail or oar was not new on the Hudson.

Three years before, for instance, a craft called the *Little Juliana* had plied back and forth between the Battery and Hoboken, manned by two boys under twenty. The *Little Juliana* had seemed far more mysterious than the *Clermont* because she had *no visible means of propulsion,* whereas the *Clermont* had two highly visible and audible paddle wheels, one on each side. It was said that the *Little Juliana* was moved by underwater wheels at the stern, which informed persons called twin screws. But in 1805 and 1806, two other boats had made trials of steam off Hoboken.

At Hoboken, across the Hudson on the New Jersey side, a point jutted into the river and there, back from the water's edge, ran the lawns of a handsome estate and on the heights above stood its owner's imposing house. If, on that August day, the owner was looking down at the Hudson and saw the *Clermont* go by, it is certain that he did not call it a miracle, for the owner was Colonel John Stevens who had built the *Little Juliana* and four other steamboats and at whose private dock some sort of vessel designed for steam could have been seen on and off for at least three years. If Stevens watched the *Clermont,* probably the only emotion he registered was one of anger that her designer Robert Fulton was being acclaimed as the inventor of the steamboat.

John Stevens had never made any such claim. Unquestionably, he was the greatest engineer America had produced and probably no American approached him in special knowledge of the steam engine. He had designed all the engines for his own boats instead of importing them from England as Fulton had done. But he knew that steamboat invention went back beyond any of his own experiments. He had been a passenger on the steamboat built by Samuel Morey of Connecticut in 1798, but he well remembered a steamboat eight years before that which carried passengers and freight on regular scheduled trips up the Delaware. So if he had been asked, as Fulton's "miraculous" monster passed his point, to tell what he knew of steamboat invention, he would have begun with that Delaware boat whose beginnings dated back to 1786. We know more today than Stevens knew of that boat's unhappy designers. We know how truly America is the background of that boat; how inseparable was its connection with early pioneer history in the United States where long, lonely rivers trailed through a savage-peopled wilderness, and with man's first efforts to win a continent which steam at last conquered.

So every narrative of steamboat invention must begin with the tragedy of John Fitch and Harry Voight.

2

On a sharp, windy morning in 1782, John Fitch stood on the quarter-deck of a keelboat in the Ohio River. She was a clumsy, overburdened craft with very little shape to her, built for big cargoes and drifting. From her deck, John Fitch could see other such boats above and below on the wide waters: barges, flatboats and pirogues, all clumsy affairs, some with houses on them and stable yards packed with cows, oxen and sheep. When travelers went down the Ohio in those days they took everything they had with them for there was no going back. When they arrived where they wanted to live, they simply ran the boat ashore, unloaded it, broke up the boat and built houses out of the timbers.

The boats were largely at the mercy of the current. Oars were used only to pull the craft to one side or the other to avoid the river's snags and islands. There was no rowing such vessels upstream against the current, so if the settlers changed their minds during the journey, they must go back overland along perilous trails. If a trader wanted to go down the river to sell goods to the settlers, he too must abandon his boat and trek back across the wilderness. Often, on the way, he would meet a gang of bandits who quickly relieved him of his profits, so trading on the river in the 1780's was a costly business and only the hardiest of men dared it.

But John Fitch had planned to go the full length of the rivers: down the Ohio to the Mississippi and down the Mississippi to New Orleans. He had put his last penny into flour and loaded it on board. He would sell the flour at a fine profit in New Orleans and come home by ship through the Gulf and up the Atlantic coast. He knew the river dangers well enough: he had been on these boats before when he had gone to Kentucky to survey the wild lands. He had seen boats caught on snags, ripped open by half-sunk trees. He had heard the crack of rifles across the water and knew that the rank growth on the shores was alive with smooth-muscled men who, though they were naked but for wampum-strung breech-clouts, carried arms and could shoot them with a deadly aim. He had argued with Captain Parkerson about the precautions he should take, but the lazy captain had laughed and called him coward.

But on this bright morning, John Fitch had high hopes. Life was beginning anew for him this spring—as it had begun anew so many times before. All his life, he had met disasters that would have wrecked most men; stubbornly, he had started over and fought his way back. As he stood on the keelboat's deck, watching the low banks and the muddy water slide past, he remembered some of these things and was glad they were behind him.

He remembered the East Windsor farm where his Connecticut Yankee father had made life so hard. Weak, undersized, John had hated the heavy haying, the plowing and planting and harvesting. "Crazy for learning," he was, as he kept saying, but his father, to save hiring labor, had pulled him out of school before he was seven. He had sneaked his education, then, reading at night and breaking the strict Sabbath by working at arithmetic problems. At ten, he had taught himself surveying.

He remembered his sudden growing at seventeen, when he shot up over six feet and, knowing then that he was a man, wanted a man's job away from the farm. That was when he had met Benjamin Cheaney driving along the road.

"I need a likely-looking young man like you," said Cheaney, "to help me at my clock-making."

The thought of clocks had blinded him to the crooked leer on Cheaney's face. To work with machines—to understand the movement of spurs and wheels and delicately balanced levers—was all he wanted out of life. He accepted the apprenticeship, but in four years, he never got beyond Cheaney's brass foundry, never saw a clock. Cheaney was too shrewd a man to let out his secrets to a boy smart enough to become a better clockmaker than he and run him out of business. What he had apprenticed John for was to work his farm and save him the expense of hired labor. For all men in those days, whatever trade they followed, were farmers first.

"If I'd known as much then," thought John Fitch as he watched the Ohio from the keelboat, "as I do now, I'd have sued him for his swindle."

But he smiled as he remembered the outcome after he had got free and come of age. He had been too ashamed to tell how he had been duped. So when he had finished his apprenticeship, the neighbors thought he was a clockmaker. He had taken a clock to repair. He had shut himself up in a room with the clock and stayed there two days. When he came out he had learned what four years had failed to teach him. Slowly, he had taken apart the works. In a frenzy of delight, he had mastered every step of the movement. He had found the fault and mended it.

John Fitch looked across the river and called back to the captain who was dropping off to sleep.

"The other boats have drifted away from us," he said. "They're out of sight."

"Yah," said the captain. "So you're worrying again, are you? Figuring on Indians?"

"We'd have done better," said John Fitch, "to keep lashed together."

But the captain was asleep, and John went back to his memories.

There was his wife, Lucy, who nagged him until he left her. He had wandered over five provinces before they were states. At Trenton, in East Jersey, he had set up as a silversmith and made money. But in '76 the British had come, looted his shop, broken his tools. He had obtained a commission in Washington's army, but when the officers found how much he knew about muskets, they put him to work as a gunsmith. Later he had got a job as a surveyor. He had made thousands of dollars in different jobs in those years, but it had been stolen or the paper currency had gone bad and he had lost it.

He shook his head to get rid of these dark thoughts. Then, suddenly, he was staring ahead and his body grew taut. Directly ahead, but still a mile or so away, lay an island. He dropped on one knee, lined up two trees on the island with the prow of the boat and squinted along the three points. Unless the crew started to row immediately, it was certain the boat could not clear. He called to Parkerson and ran below to take an oar. But it was ten minutes before the captain gave orders to row. John Fitch, below, where he could see nothing, suddenly felt the ground beneath him and the prow rising on the sand.

They had to unload the boat to get her off. Dark eyes watched this work from the shore and a message was sent among the red men in the woods. Then the bullets came. Two men on the boat were killed. John Fitch begged the captain to fight back. But Parkerson, in a panic, surrendered; the Indians came aboard, scalped the dead men and took the others captive.

3

The virgin forest stretching away from the north bank of the Ohio below Fort Pitt must have seemed a long way from the war with England which was then in its last year. Yet the story of Fitch, from the moment of his capture, becomes, for a time, involved in that war. The fact was that Indian trails led north to the water route that divided the colonies from Canada. The Indians who moved eternally along these forest trails, recognized no boundaries and treated or fought with British and Americans alike when they encroached on the tribal domains. The British had decided that it was to their advantage in the war to encourage the tribes along the border to bring in American captives and to reward them with the prizes dearest to the Indian heart—muskets and ammunition. Thus, after weeks and incalculable miles of trek over the dark trails, Fitch found himself a prisoner of war on a British island in Lake Ontario.

The island being far enough out to make escape impossible, and war being, in those days, a more gentlemanly affair than it later became, the prisoners were lightly guarded, treated with a degree of friendliness by their captors and allowed to do much as they pleased. Most of them, Fitch found, pleased to do nothing. All day they lay in the sun, exchanging stories. To John Fitch's intensely active mind, such a life was intolerable. So, to the annoyance of the others, he at once started to work. The account of his work, written in his diary with fantastic spelling and almost total innocence of grammar, is one of the most remarkable records of unschooled genius in the whole history of invention.

"All the tools I had," he wrote, "was my old Graver and no steel on the Island to make any with. And all the tools I could find on the Island was an ax, a handsaw, a Chissel, and Iron Wedge fr splitting wood, and a shoemakers hammer, also a fore plain. My first thought was to make a Vice, but before I could make that, I must have a turning lath, to turn the screw; with the saw, ax; Chissel and fore plain, I got it compleated. I ought also to have mentioned, that there was an augure and grindstone on the Island. I got a peace of ramrod of a gun, and made the Centures for my Popets; I also got a large blade of a jack knife, and broke it in two, one part of which I made a Chissel, the other a Gouge for turneing. The Iron wedge I fixed in a Block, and made my anvil. The shoemaker's hammer I forged with, and our common fire, blowed by my mouth or hat, I forged by. I made a punch out of an Iron hoop, and punched two holes thro' each Broken Blade, and then took an iron hoop and punched two holes at each end uniform with the first, and bent the hoops, I Riveted the Broken Blade between the ends of the hoop, and after the Chissel and Gouge was made and hardened, filled the hoop with wood, which made a very good handle. Thus I got my lath completed. . . ."

With this homemade lathe, he made his vise and soon after he was drawing wire and producing other small bits of hardware. At first his industry was regarded with resentful contempt by his fellow prisoners, but after a while two or three other Yankees, bored by the idleness as he had been, joined him. Soon the little group was making things for sale. They found an old brass kettle and made it into buttons which John carved. From coins they made silver buttons. In five months they made nine wooden clocks sold at $4.00 each, three hundred pairs of brass sleeve buttons and eighty pairs of silver buttons. In addition to this, John repaired watches and harvested a good crop from a vegetable garden. When the war ended, he was actually sorry to be released!

They sent him by ship to New York and let him go. With a fellow prisoner, he made his way to Bucks County, Pennsylvania, and there, in the town of Warminster on the Delaware River, he tried to start a new life as a surveyor. His hardships had given him severe rheumatism and he was forced against his will to rest much of the time. Yet in that next year he managed to survey some 50,000 acres.

4

One Sunday morning in the spring of 1785 he was limping home from church, arguing with a friend, James Ogleby, about the sermon. The two men were deep in conversation when a carriage with a high-spirited horse dashed by them. John Fitch watched it disappear and after that he forgot about the sermon.

"I wish," he thought, "I hadn't sold my horse. I could use him now with this lame leg of mine. Well . . . I can't wish him back. But there's a substitute for almost everything in the world. What substitute for a horse?"

It was strange the way the thought laid hold on him, tormented him, would not let him go. For three weeks he kept figuring how some powerful force—like the force that came from heat—could be applied to the wheels of a wagon. There was terrific force in a teakettle when the water boiled. Could steam be applied to a wheel?

It was the Bucks County roads that stopped him. When he saw the mud and ruts after the spring rains, he knew that no kettle could run wheels through them. His eyes strayed, then, to the Delaware River beyond the roads and his mind went back to the Ohio.

His thoughts leapt from point to point in his memory. A machine in a boat . . . steam to turn it . . . a boat moved by steam . . . away from islands and snags . . . fast, away from Indians . . . *upstream, even, against the current.*

A frenzy seized John Fitch then; he could not sleep or rest. Night and day he drew and whittled, watched the boats on the Delaware.

He went to the most educated man he knew, the Reverend Nathaniel Irwin, who was a graduate of Princeton College.

Nathaniel Irwin smiled at the careful drawings. Then he took down a book from the shelf over his desk and opened it to a picture.

"I think," he said, "this engine might work better than yours."

John Fitch stared at the page. Then he closed the book, threw it on the desk, got up and paced the floor.

"So," he said. "I have invented nothing new. I thought to make a fortune."

"You may make it yet," said the minister, "with your boat. But is it possible you have never heard of a steam engine? They have been used in England for near a hundred years."

"I have no education. That is my luck."

"But no one has put an engine in a boat. No one, John, has set this thing to run a boat. Have you worked out your propelling mechanism? That might be an invention if it worked."

"If it worked," said John, "it would change the whole of the West. It would make a poor land rich. It would bring unimaginable wealth."

John Fitch found a wheelwright's shop in Warminster town and a young man, Nathaniel Boileau, who was on vacation from Princeton College, helped him. John Fitch made a model boat two feet long and Boileau whittled a circular paddle wheel. They tried the model with no engine and it seemed as if the paddles would be hard to work, for they hit the water too flatly and, as they came out of it, lifted much water with them. So John Fitch worked out an endless chain running over sprocket wheels. To the chain, paddles were attached so that they entered the water at right angles. Irwin approved the design.

"You must show it to men of influence," he said. "Get their approval. Get letters from them. Show their letters to the state legislatures and, maybe, the Congress. You can't do anything in this country until you have got influential men behind you."

And money, thought John Fitch. First, last and always, money. In the time since his release from the British prison he had drawn a map of what was called "The Northwest." This was the immense, unsettled territory from the Ohio River north to the Great Lakes and west to the Mississippi. He had used other maps as a basis and had put in new information gathered through his own surveys and in his forced travels as a captive. He had engraved his map on copper and used an old cider press to print it. He had hundreds of copies. He could sell them easily for about a dollar each, for there was wide interest in frontier lands. With his maps he got his start on the steamboat. He bought a horse and two-wheeled cart, put in it his model and his maps, and started out.

In Philadelphia he called on Doctor John Ewing, Provost of the University of Pennsylvania. The intense fire of Fitch's black eyes, his strange, inspired look, his plausible words and drawings, and most of all his model, brought forth exclamations from the doctor. He gave a testimonial and a letter of introduction to a friend. From then on, John Fitch's hopes were high. He got letters from Samuel Smith, Provost of Princeton, and from several delegates to the Continental Congress. But when, in September, he arrived in New York and presented a petition to Congress itself, which was in session in the city, it was referred to a committee and from there found its way to the scrap basket. The Congress, which was trying in 1785, without a Constitution to follow, to work out something which looked like a sovereign nation from thirteen sovereign states—all of them jealous and some even hostile to one another—was too busy to bother with steamboats.

John Fitch called the delegates "ignorant boys" and went traveling again. He got as far as Virginia, interested the Governor, Patrick Henry, persuaded James Madison to interest the Virginia legislature, but no one offered him money. His horse brought him back to Trenton and there, with his pile of important letters, he induced the New Jersey legislature to grant him the exclusive right to make and operate "all and every species or kind of boats or water craft, which might be urged or impelled by the force of fire or steam" within the state for fourteen years from March, 1786. This was his first real triumph. It gave him enough prestige to start a stock company for steamboat making.

The stockholders were all respectable businessmen, not rich and certainly not idealists. They did not start the company to promote the "useful arts," as invention was called. They started it to make money.

At their first meeting they talked about engines. John Fitch had gone cheerfully ahead so far with a boat and a paddle chain. How about this "condensing, atmospheric machine" that was to "urge" the boat through the water? Had Mr. Fitch ignored that?

Not a dozen men in America knew anything about steam engines. In the thirteen states there were only three actual engines all built on the Newcomen pump principle. Steam was let into a vertical cylinder and condensed there. This created a partial vacuum which enabled atmospheric pressure to push the piston down. With the vacuum destroyed, counterweights raised the piston and new steam was let into the cylinder for a repeat performance. The Newcomen engine repeated this act twelve times a minute. John Fitch knew as soon as he studied this that it would not get a boat very far or very fast. So when the company got the most likely man they could think of, John Nancarrow, who had actually operated an engine, to draft a plan, Fitch shook his head.

"No," he said. "It's the same old principle. We must get something new."

The stockholders fretted and fussed, as John Fitch walked in the Philadelphia twilight. His favorite street in the city was the street of the clockmakers. He had never got over his itching curiosity about the works of clocks. He went into a shop just before closing time and met the Dutch clockmaker. Fitch was so impressed by this young man that he wrote of him in his diary that "a superior Mechanical Genius was not to be found on earth." They talked all night. Then John Fitch went to the stockholders and told them that Harry Voight would make their engine.

First Voight built a model with a one-inch cylinder. It was probably the first "two-way" steam engine in America. Neither Voight nor Fitch seemed to have heard of an Englishman, named James Watt, who had just patented this idea. In their model, expanding steam forced the piston one way in the cylinder and then, being let in at the other end, forced it back. The little model worked neatly. So they made an engine with a three-inch cylinder, put it in a skiff and rigged the chain of paddles on the outside. A crowd of boys and men came down to the river to watch. There was too little power, the paddles had no effect and the crowd jeered. The boat had to be rowed back.

Harry Voight, in common with many geniuses, was a proud, temperamental and sensitive person. The public humiliation at the river was too much for him. He slunk away, before the crowd had begun to associate him with the failure of Fitch's boat, and disappeared. Fitch, deserted by the only man who had offered him real hope of success, went to a tavern and got very drunk.

He woke early in the morning after two days of semiconsciousness. He was suddenly clear-minded and cool. He was angrily ashamed of himself. As he lay in his bed, cursing his weakness, a sharp, simple picture came to him.

He saw a boat paddled like a canoe with six paddles on a side —three forward, three aft. By joining each set of three paddles together with a rod, and connecting the rods to cranks, he could make the two forward sets dip into the water at the same moment that the two after sets came out of it. Then, as the wheel turned, the forward sets would pull back through the water and the after sets would move forward and be ready to enter the water as the forward sets came out. In John Fitch's mind, then, the reciprocating motion of the cylinder was translated into rotary motion in the wheel and back again into balanced, reciprocating motion in the canoe paddles. To later mechanics the plan seemed easy enough, but when John Fitch, waking from a drunken sleep in the spring of 1786, evolved it, the crank or eccentric principle had never been applied to steam engines in America.

He got up, lest the idea escape him, drew it out on paper, and, forgetting about his friend's desertion, ran to Voight's house. Voight evidently was so fired by Fitch's idea that he too forgot his injured pride. At any rate, from that moment, the two worked in a fever of excitement. By July, they had the new machinery in the skiff; it worked, and the boat was actually propelled against the current of the Delaware.

The stockholders were happy, and several of them played with the boat for a few days. Then there was a meeting and the businessmen said it was a nice toy sure enough and what would it cost to build a real boat to carry passengers and make money?

A twelve-inch cylinder would drive a twenty-ton boat from ten to fourteen miles an hour. John Fitch was sure of it. But the businessmen got out paper and quill pens and when they had figured costs and called for a treasurer's report, which showed an alarming minus balance, they shook their heads. So John

Fitch was forced to forget his brave plans and go out to gain more prestige.

This time he got the legislatures of Delaware, New York and Pennsylvania to grant him monopolies. He was immensely persuasive on these political tours. He developed a power of language and his eyes blazed with the intensity of his faith, as he kept repeating that his invention would make all the country northwest of the Ohio "four times as valuable." He persuaded the influential *Columbian Magazine* to print an article about his boat and a picture of it. He got everything but money. But the stockholders were impressed by the new publicity and again they dug into their pockets.

For two more years they struggled. John Fitch would have starved but for the friendship of the woman who kept the lodging house where he lived. Down at the heel, out at the seams, thin, gaunt and hungry, only the steady burning of his eyes showed that his faith was still moving his clear mind and his tired body. But in the fall of 1789, a new boat was finished and there was a little time of triumph for the inventors.

"We reigned Lord High Admirals of the Delaware," John Fitch wrote in his diary after the trial, "and no boat in the River could hold its way with us. . . . This had been effected by little Johnny Fitch and Harry Voight, one of the greatest and most useful arts that has ever been introduced into the world; and although the world and my country does not thank me for it, yet it gives me heartfelt satisfaction."

During the summer of 1790, the boat made scheduled trips up the Delaware and carried many passengers. She was capable of eight miles an hour and regularly ran about seven. The propelling mechanism had been changed and this boat was moved by paddles in the stern which rose and fell and pushed against the water.

The Governor of Pennsylvania and many distinguished Philadelphians made trips on her. They were enthusiastic. Several of them subscribed for a silk flag to be presented to John Fitch by the Governor although, in the end, the Honorable Thomas Mifflin lost his nerve and feared the catcalls of the crowd which still jeered at the steamboat. And, as the summer drew to a close, the stockholders, in spite of the dozens of safe trips the brave little steamer had made, came to the conclusion that maybe the crowd was right after all. For when they balanced up their books and set the total passenger fares against the cost of fuel, repairs and the inducements by free grog and sausages which had been offered the passengers, they discovered that there had been a loss on every trip.

To later readers of Fitch's story, the abandonment of such a venture on the very threshold of success, has seemed a cruel thing. But the nation was young in 1790. There was very little money. In the years after the war, the whole country had nearly gone bankrupt. Fear swept through the thirteen states year after year as the currency depreciated, as poverty increased on the farms, as the Congress even refused their long overdue pay to the soldiers who had won the fight for independence.

A few of Fitch's stockholders got together and reorganized half-heartedly, but his fourth boat, tragically named the *Perseverance*, was never finished. And when the money stopped for good, John Fitch's friend Voight again deserted him to save what he could of his own reputation

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The broken inventor lived on charity for a year. Then, as if Fate, which sometimes seems to play with men as a cat plays with a mouse, could not let him drop, his hopes were raised once more.

A man named Vail had seen the last boat on the Delaware in the days of its triumph and could not forget it. This Aaron Vail was United States Consul at L'Orient in France. He told the story of the boat to the French government and got a contract which would pay Fitch's expenses to come to France and build a steamboat there. So John Fitch, after giving up hope, found himself sailing from New York with his pocket full of money in February, 1793.

He met Vail, gave him all his plans and drawings and went to the big foundries at Nantes to see to the making of his castings for his cylinder. As soon as he came back, the French Revolution reached Nantes and John Fitch was forced to give up all hope of getting an engine built. Vail could not help him further than to suggest he go to England, try to get an engine and bring it back after the war was over. He went, and in the great steam engine works of Boulton and Watt, he saw the engine which Watt had invented and which embodied Fitch's own ideas and Harry Voight's. It seemed to him perfect. If he could buy such an engine, transport it to France and put it in a boat there, he would be able to complete his French contract.

Again and again, he wrote to Vail at L'Orient, but now all France was in the total grasp of the Revolution and communication was cut off. There was no hope of getting back to France, either, to report to Vail or to get back the drawings he had left with him.

It ended by his money giving out in London. So he took ship for home and worked for his passage.

By now he had stopped writing his diary. The story from here on is broken. Somehow, in New York, he got enough money together to try one more steamboat on Collect Pond in Manhattan, but it was a futile gesture and his last.

He went back to Bardstown, Kentucky, where there was a tract of land, which he had bought as he surveyed it and which still belonged to him. He made a deal with a tavern keeper, giving him the land in return for a promise to feed him and supply him with a pint of whiskey a day as long as he lived.

A while after that he grew sick, suffering constantly from headache so that he could not sleep. A doctor gave him some sleeping pills to be taken one every night. John Fitch went six nights without taking a pill. On the seventh night, he took all seven.

He was buried in an unmarked grave in Bardstown.

5

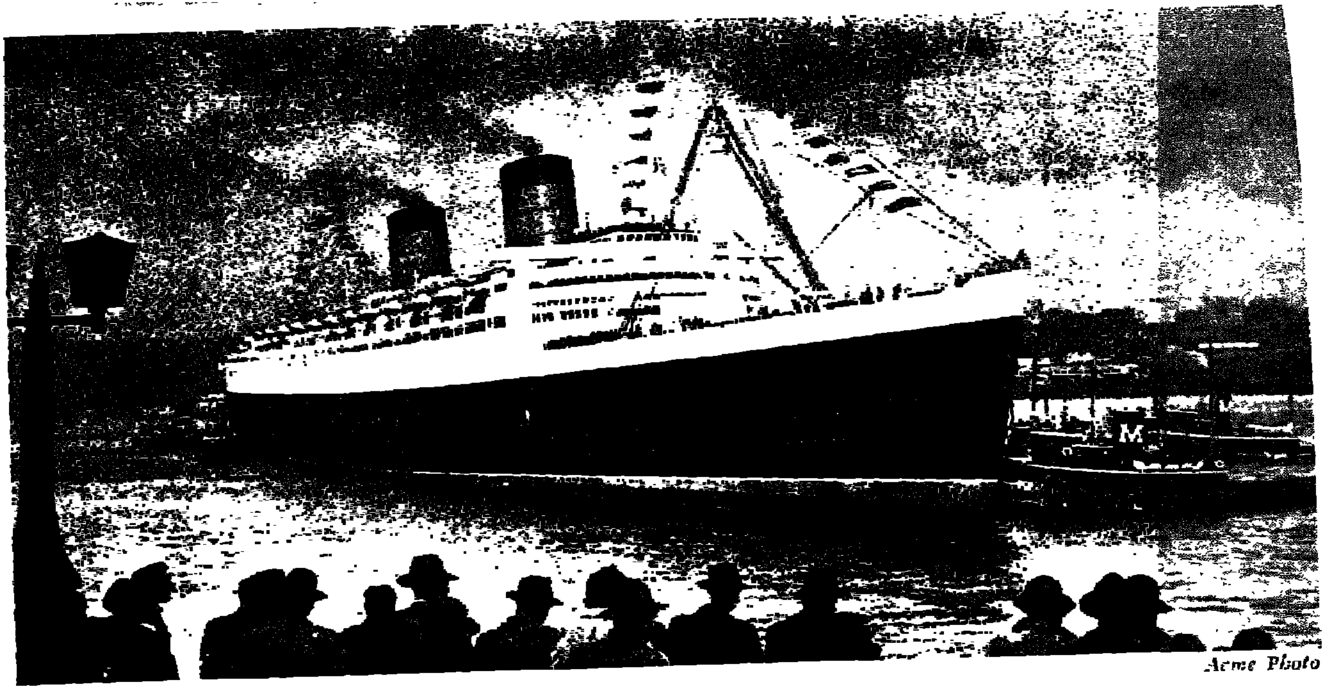
There is less tragedy in the next chapter of steamboat history, though some of the people in it lack the nobility of character we like to associate with popular inventive heroes. John Stevens knew that chapter in detail as he watched the *Clermont* on its trips to Albany in the summer of 1807, for he had been its principal character.

As soon as he heard of Fitch's experiments on the Delaware in 1788, and of other, lesser attempts by James Rumsey who insisted on moving his boats by jet propulsion, Stevens saw at once the source of all their troubles. "This," he wrote, "was the great weight and bulk of the boiler, when constructed in the usual manner." He knew that before a boat could make anything approaching speed, something must be done to eliminate the overload caused by such clumsy affairs as Harry Voight's brick furnace and the big, heavy parts of the engine which dragged the wooden boat down in the water and shook it to pieces with vibration as it moved.

Stevens's approach via the engine was a sensible one, but it was difficult in a period when the science of thermodynamics was almost wholly unknown in America and when the boring of a cylinder was a hand job, at best grossly inaccurate. At the time when his interest was first aroused there were probably not half a dozen steam engines of any kind on the whole American continent.

Somehow, steam must be generated more quickly and from a lesser bulk of water than by the teakettle method. Stevens tried shooting jets of water at hot pipes and then introducing a number of flues into the boiler to increase the heating surface. What he was groping for was the multitubular boiler independently invented by Nathan Read of Salem and patented by him in 1791. Read had two alternative methods in his mind: one of which consisted of tubes filled with water moving through a firebox. The water-tube idea was the one which Stevens worked on and improved because it cut the size of his boiler.

It was while John Stevens was engrossed in this intensive study of engines that the second of the principal characters in this second chapter of steamboat history entered the story. Some twenty years before, John's sister Mary had married a brilliant young man who even then gave promise of statesman-



Acme Photo

LONG TRAIL

Countless forgotten inventors followed in the wake of Fitch and Stevens before the Queen Elizabeth *set out on what Kipling calls "the trail that is always new." But this giant of the seven seas with her propellers seems to come nearer the dream of John Stevens than to that of Robert Fulton.*

Acme Photo

VICTORY

This photograph illustrates a triumph of mass-production as it is applied to the building of a power-driven ship. The victory ships constructed during the war were assemblies of "prefabricated" sections. Following Eli Whitney's, Samuel Colt's and Henry Ford's contributions to the interchangeable parts system, they are far beyond any dream of the early steamboat inventors.

ship.

The Livingston family was true landed aristocracy—rare in America. The original Robert had been called "first lord of Livingston Manor," and the manor was as nearly a feudal estate as anything in the American colonies. Through the generations following him, the eldest son was always Robert R., an abbreviation for "Robert son of Robert." This Robert R., of the steamboat saga, great-grandson of the first lord, in spite of a background foreign to American custom, was a fervid supporter of the Revolution, helped draft the Declaration of Independence and later established the Department of Foreign Affairs which became the State Department. Besides these activities, he went deep into the politics of New York State and was called "Chancellor."

It would seem that all these activities would have kept him too busy for steamboats. However, like Franklin, he had an inventive and mechanical turn of mind—though unlike Franklin, he was more of a gadget-fancier than a scientist. In his spare time, he dabbled in new inventions and ideas and, though many of his theories were thoroughly impractical, his wealth and position made him arrogant about his half-knowledge, and he was always trying to force his fancies down the throats of real experimental engineers.

His brother-in-law, John Stevens, was often irritated by his suggestions, but when Livingston caught the steamboat fever, Stevens welcomed his interest because it seemed to promise unlimited financial and political aid to the great project. But this did not happen until another character had come upon the scene—a person so vital and so important to the history of

American river navigation that even the Fulton legend has never quite succeeded in dimming his glory.

Nicholas J. Roosevelt was fourteen years old in the summer of 1782. In him were combined a robust body and an intensely active, resourceful mind. In that last war year, his home and his father's shop in New York City were in the hands of the British and the family was living on a farm near the Hudson River village of Esopus. The farm had a pond with a flat-bottomed boat on it and a workshop. Nicholas spent his time between the pond and the workshop, and the device he built that summer remained a vivid picture in his mind for more than seventy years. It was a pair of paddle wheels, hung over the side of the boat on a horizontal axis and turned by the unwinding of a cord by hickory and whalebone springs. The wheels moved the boat—not fast, not efficiently, for reasons afterward encountered by Fitch—but the experiment is important because of later conflicts with Livingston and Fulton.

When the war was over, Nicholas returned to the city and devoted himself to the study of metal working in the hardware shop of his brother, Jacobus. He became a skilled artisan. He was twenty when he first heard of John Fitch's canoe paddle boat and this revived his excitement over the side-wheel idea which he was convinced was more practical than the reciprocating paddles, but by that time he was too busy earning a living to experiment further. But he did turn his attention toward steam engines, and when he was twenty-five he had saved enough money to buy an iron foundry on the Passaic River in New Jersey which he planned to devote to engine-building. He named the new plant "Soho" after the famous

Boulton and Watt engine works in England.

The story is told that Roosevelt first met John Stevens and his brother-in-law, Chancellor Robert Livingston, at Collect Pond in New York City while John Fitch was making his last, desperate gesture with a small steam-powered yawl, said to have been propelled by a screw propeller. Historians are unsure about the story; there are no documents about it and it has seemed a little too dramatic. Yet it is plausible enough that three of the most absorbed followers of steamboat news, all living in or near New York, should have gathered to watch a steamboat experiment made by its foremost inventor.

In any case, we know that by 1797 Stevens was searching eagerly for a practical engine-builder, and had almost interested Livingston to the point of investing capital in engines. By the following year an agreement had been made among the three to build a steamboat, with Stevens and Roosevelt doing the work and Livingston standing on the sidelines, stubbornly interfering with technical details but at least supplying part of the capital.

We have the record, during this time, of repeated insistence by Roosevelt on the use of vertical side-wheels and of Livingston's repeated, obstinate refusal to consider them. The result was the *Polacca,* driven by a stern paddle wheel at three and a half miles per hour on the Passaic. She was not a success, but her engine, which Livingston left to Roosevelt and Stevens, was double-acting, had a cylinder twenty inches in diameter, a twenty-four-inch stroke, and seems to have been an advance on anything yet built in America.

While the *Polacca* was being built, Livingston, in addition to giving advice, moved his steamboat ambitions into the political ield and, having great political influence, got a law passed iving him "the exclusive privilege of constructing, making, ising, employing and navigating all and every species of Boat r watercraft which may be urged or impelled by the forces of fire or steam," on any waterways of the state for fourteen years, provided, however, that within a year he should have ready a boat of at least twenty tons capable of making four miles an hour on the Hudson.

The *Polacca* failed to meet these conditions. So Livingston, whose influence on the state legislature had not diminished, had the law extended to twenty years without conditions. Counting on Stevens and Roosevelt, he entered into a three-cornered agreement by which all were bound to share in any steamboat project initiated by any of them during that time.

Now comes the part of the story which casts a shadow over the scene almost as dark as that which defeated John Fitch. The only difference was that Stevens and Roosevelt being successful men in other fields and, having reasonable means of livelihood, survived, whereas John Fitch, poor, friendless and disheartened, ran down the rails of his single-track desire to his death.

In 1801, Livingston, who was being showered with honors from all sides, was appointed Minister to France. Naturally, with such a heavy responsibility on his shoulders at one of the most critical moments in European history when Napoleon Bonaparte had just taken his first step toward imperial power, the new minister forgot about steamboats.

In Paris, however, he met and took a great fancy to an inventive young artist, Robert Fulton, who was engaged in spectacular experiments with what he called a "diving boat."

Fulton expressed an interest in steamboats, having studied the experiments of Symington in England. Livingston told him, then, of everything Stevens and Roosevelt had done and introduced him to Aaron Vail, the consul with whom John Fitch had left all his plans. They talked with Joel Barlow and Thomas Paine, also friends of Fitch and steamboat enthusiasts. Eventually, after he had brought Fulton abreast of everything which had been done, and discussed all the plans, specifications and projects which could be found, Livingston financed Fulton in the building of a boat and launching it on the Seine. The boat sank and they made another which remained afloat, but developed no speed. Fulton's success with engines was so far below that of Stevens and Roosevelt, that he finally determined, with Livingston's help, to buy an engine ready-made in England, ship it to America and carry on there. So he sent an order to the celebrated Boulton and Watt.

It took two years to deliver the engine. England was jealous of American progress in the mechanic arts and had strict laws against the export of any British machinery which Americans might copy or improve upon.

In Hoboken, meanwhile, John Stevens, ignorant of his distinguished brother-in-law's new activity, went persistently ahead—sometimes with Roosevelt's assistance, sometimes on his own. In 1802 he began with the screw propeller (first invented by David Bushnell for a hand-driven submarine during the Revolution) and launched a single screw boat with a high-pressure turbine engine. In 1804, he launched the twin-screw *Little Juliana* and in 1805 a larger boat. In 1806, he started construction on the *Phoenix,* a hundred-foot ship.

Then Livingston and Fulton came home. They commissioned a New York shipbuilder named Brown to build them a boat. Stevens became interested. According to the agreement, he was still Livingston's partner in any enterprise on the Hudson. Certainly, this new boat (on which work was progressing so rapidly that it soon was evident it would be completed before the *Phoenix*) would be launched upon the Hudson and with its British engine would operate there. Would he and Nicholas Roosevelt share in this operation and, perhaps, combine it with the operation of the *Phoenix* into a commercial enterprise?

Livingston was embarrassed. His new partner, Fulton, though unquestionably a genius, was difficult. He had grown so convinced of his own powers that he was jealous of his success. Although he had profited by his knowledge of the Stevens experiments, he now regarded Stevens as a comparative amateur. Furthermore he wanted nothing to interfere with the credit he might get as inventor of his boat. Livingston, however, had his brother-in-law on his conscience. So despite the protests of his new partner, he wrote the Colonel offering him partnership with him and Fulton—not mentioning Roosevelt—on condition that Stevens put up one third of five thousand dollars!

Stevens naturally refused. He had already contributed his share to the original partnership with Roosevelt. Also, he saw no reason why Roosevelt should be dropped. Finally, the whole thing seemed to him a breach of contract.

When Livingston's offer was declined he felt free of all further obligation. He went ahead with Fulton and by the time the new boat was launched he had got Fulton's name included in the grant of monopoly. The boat was named *Clermont* after

Livingston's Hudson estate.

So when Stevens watched the *Clermont,* equipped after all with Roosevelt's side-wheel invention and powered by James Watt's engine, on her Albany voyages he knew that he would have no share in her success. This alone did not greatly disturb him. The galling, unforgettable hurt was that by the terms of the Livingston-Fulton monopoly, he was forbidden to run his *Phoenix* or any other boat on the Hudson.

In court, Stevens might have found justice, in spite of Livingston's prestige. But he could not afford a long lawsuit. Furthermore, the idea of a court battle with his own sister's husband was repellent to him. So he launched the *Phoenix,* sent her on a perilous sea voyage to Philadelphia, which was outside the monopoly's jurisdiction, with his young son Robert in command, and thus established the date—June, 1809—of the first ocean steamer in the world's history. Fifteen years later, in one of the most famous decisions ever handed down by a chief justice of the United States, John Marshall declared that the Hudson monopoly, in conflict with federal patents, was not, and never had been valid.

In 1807 and 1808, Livingston and Fulton, favored by fortune and the Chancellor's prestige—enhanced by masterly diplomacy abroad—were able to establish the first successful commercial steamboat enterprise in history. The *Clermont,* with its substantial engine, built in the world's best shop, and its side-wheels to which Fulton had won Livingston over, embodying the improvements of many inventors, was a reasonably sound craft capable of carrying passengers and freight from New York to Albany a little more quickly than a stagecoach.

Fulton was so proud of her that he invited public inspection of her inside and out, including all the machinery. Some of those who accepted his invitation were less delicate and law-abiding than Colonel Stevens. Without scruple, they took from Fulton what Fulton had taken from Morey, Symington, Roosevelt, Watt and others, built boats of their own and defied the monopoly. Within a few years, competing steamers dotted the Hudson despite all the money Livingston and Fulton could spend to restrain them. Through this competition and through the spreading of "steamboat fever" outside the monopoly area, this great new force played its part in the whole country's development. In 1811, Nicholas Roosevelt realized Fitch's dream by taking his *New Orleans* down the Ohio and the Mississippi to the Gulf and back again against the current.

Fulton died in 1815. The monopoly had been broken on the river, though it remained in the statute books. From the moment of his death, the fame of Robert Fulton grew to fabulous dimensions. His funeral in New York was accompanied by salvos of guns, a procession, official mourning and oratory. Ten years later, when twenty-nine steamboats gathered off the Battery to celebrate the opening of the Erie Canal, a New York paper said:

> "It was impossible to behold the wonderful movement upon the waters, unaided by a breath of air, without feeling how vast a debt of gratitude we owe, and the whole world owes, to the mighty genius of our immortal countryman, Robert Fulton."

Meanwhile Fulton streets, parks, markets, monuments and buildings appeared in coastal cities. Steam craft, from warships to excursion boats, were named *Fulton.* Through the century, halls of fame, historical museums bristled with Fulton busts; school books, classroom teaching, erudite histories, patriotic speeches omitted all mention of Fitch, Rumsey, Morey, Read, Stevens and Roosevelt. Finally in 1909, New York staged its Hudson-Fulton celebration, coupling the discoverer of the river with the "inventor" of its "first steamboat."

It is only in late years that Americans have begun to comb their histories with skepticism. In 1926, for instance, the United States Congress unanimously declared that John Fitch was "the real inventor of the steamboat" and appropriated $15,000 for the erection of a monument to him at Bardstown, Kentucky.

To John Stevens, whose later career was essential to the beginning of American railroads, and whose son, Robert, skipper of the *Phoenix,* carried on the engineering tradition, there stands a memorial far more valuable than all the bronzes and portraits and cornerstones we have dedicated to our popular heroes. Towering above the lawns of the old Hoboken estate and the waterfront where the *Little Juliana* docked, is the Stevens Institute in which thousands of young Americans have been educated to be engineers in fields beyond the Colonel's brightest dreams.

4

TRUE HEROES OF THE TELEGRAPH

1

WATCHING THEM AS THEY STOOD ON CHAIRS STRINGING THE copper wire, it was hard to tell which was older, the boys or the professor. Joseph Henry's body was as supple as his pupils'; his face, especially as it lit up with some quick enthusiasm, seemed as young as theirs. Young Dr. Ten Eyck, who stood on the floor unreeling the wire as the boys drew it again and again round the walls of the big room, remembered sharply the look of the professor's face one night a few years back when it had been flushed with the excitement of an idea.

They had been sitting talking, as usual, in Henry's study. Philip Ten Eyck, in the evenings, used to forget his medical practice. The professor had grown dependent on him as an assistant in his endless work, and Ten Eyck would often stay all night without any sleep.

Suddenly, the professor had put out his hand and touched his knee to stop him talking. For a long interval, there had been no sound but the clang of the old wooden-wheeled clock as it struck four and the long undulating overtones that hung in the air afterward. Joseph Henry held his chin in his hand; his arched eyebrows had drawn down to a straight line with the puzzle of his thinking. Then he had jumped to his feet, and a light had come over his face making it seem translucent with brightness from the inside.

"Tomorrow!" he had shouted. "Tomorrow I shall make a famous experiment. Go to bed, Ten Eyck, so your eyes will be open to see it. As for me, I don't feel as if I should ever sleep again."

And the next day he had shown the class the fruit of his long vigil: sixty feet of copper wire wound with silk thread. Then, winding the wire round the magnet bar, he said,

"See, the wire is insulated from itself as well as from the iron. I need not space it, but wind it close so the wire will lie at right angles to the core. That will multiply the power of the magnet, but also I can wind any amount of wire on it."

The boys all knew by now how famous the experiment had become. Thousands of people had seen the new magnets lift a hundred, then three, six and seven hundred pounds, and today, in England, Faraday was using electromagnets wound with wire that was insulated from itself by silk.

The young doctor, now, as he helped Joseph Henry prepare a new demonstration, grew so bemused by his memories that, when the professor called to him, his voice seemed to come from far away.

"How much more, Ten Eyck?"

"Enough for twice more around."

"Good. That will be over a mile. So they have not cheated us."

When the job was done, the tired boys got down from their chairs and stretched.

Henry laughed quietly.

"Go out now," he said, "and tell the class I'll be ready for them in ten minutes. And, if you're not too exhausted from your labors, you may come with them."

When they had gone, Joseph Henry opened the bag he had brought from his study.

"Now for the show."

Dr. Ten Eyck had no more knowledge of what the professor meant to do with his wire than the boys. It was Henry's way, when he planned his great demonstrations, to keep the details secret in advance. He had the showman's instinct, a deep dramatic sense. For years, before his mind had turned to science, he had been an amateur actor, president of an Albany dramatic club. He had been a boy in his teens then, but Ten Eyck had seen some of his brilliant performances and Ten Eyck knew that it was partly his actor's talent that made him such a great teacher. His demonstrations, with their mystery and their suspense, were so striking that the boys could never forget them.

From the bag, Henry took a little bell mounted on a stand. He carried it to the recess of the big window where the wire began and ended. Beside it, he set a pivot, also on a stand, and, in perfect balance on the pivot, he put a bar of steel ten inches long. At one end of the bar, on a pile of books, he laid a horseshoe magnet with hundreds of turns of fine wire wound about each branch. The ends of this he connected with the ends of the wire that was strung round the wall.

"There," he said. "Set the magnet so that the end of the bar is between its two poles."

The professor went quickly across the big hall to adjust the battery. It was a long battery of twenty-four cells or "pairs," as he called them, a pair being one copper plate and one zinc plate immersed in dilute acid. They were all connected in series. With a shears, he snipped the lowest round of wire on the wall, attached one piece to one end of the battery and left the other piece suspended over a little cup of mercury which was soldered to the near end of the battery. The boys were already filing into the room, talking in subdued excitement.

When they had taken their places, Joseph Henry walked to the front of the platform. The room was tense with silence and the professor felt that familiar click in his mind that perfected the connection between himself and the boys—as if they, and he too, were joined in the great electric circuit and the "mystic fluid" flowed through them all.

"Go over to the battery, Bradford. Connect the wire at this end when I tell you. Gentlemen!"

The seniors liked the dignity of Professor Henry's address. They liked the quality of his voice and its inflection—the voice of a man talking intently to his equals.

"Gentlemen, you remember my lectures on quantity and intensity. You have seen our quantity magnets lift more than seven hundred pounds.

"You remember that our quantity magnets were made of many short pieces of wire wound over one another round a soft iron core. We connected those wires to a single pair of copper and zinc plates in acid. The plates were large and the pair and acid together occupied about a cubic foot of space. You were surprised at the tremendous weights this *quantity* magnet attached to a *quantity* battery could lift."

A murmur of memory ran through the room.

"But when we tried putting the magnets in a long circuit—a circuit a thousand feet long, the power left them. The electricity apparently could not travel so far.

"I told you then that this failure of the magnets had put an end to every attempt in Europe to make a telegraph. Peter Barlow in England wrote an article in 1825—what was that, six years ago?—to *prove* that the telegraph was impossible."

The professor smiled and there was subdued laughter in the corners of the hall.

"It is difficult to *prove* that anything is impossible. After you've proved an impossibility someone always seems to come along and do the impossible thing.

"You gentlemen were not here when I first lectured on the possibility of Mr. Barlow's impossibility, though I've told you about it since. I will repeat. If you wind a single long wire round your iron instead of several short wires; if you make hundreds of turns with that one long insulated wire, you will have what I call an intensity magnet. If you then make a battery of twenty-four pairs of zinc and copper plates instead of one pair, you will have what I call an intensity battery. Now if you connect the intensity battery with your intensity magnet, the power will be the same over any distance as over a foot or two of wire. Your intensity magnet won't lift such heavy weights. But it will lift the same weight a mile away that it will lift a foot away."

Some of the boys, who remembered, nodded their heads, but others frowned in bewilderment and one or two smiled in frank skepticism.

"I know it's hard to accept."

A hand went up and Henry recognized Orlando Meads.

"Have you told Mr. Barlow of this?"

"I have published it. But Englishmen never read American journals. They think most of us are red Indians over here. But if *you* understand it, that is sufficient satisfaction to me, Meads.

"There is more than a mile of wire hung round this room. Can you see it? Here in the window is our intensity magnet and a steel bar and a bell. The magnet is in the circuit with that intensity battery over where Bradford is standing. Will you dip that wire, Bradford, in the mercury cup?"

The bell in the window rang and a gasp ran over the room. There was an instant, then, of suspended silence and, suddenly, the boys were in an uproar, clapping, cheering, stamping on the floor.

Joseph Henry's face was bright with pleasure and amusement. He went to the front of the platform and bowed like an actor receiving his applause. Then the smile left him and he said,

"This is not magic, gentlemen. It is only electromagnetism."

But the boys would not be quieted. Orlando Meads shouted:

"But it is a telegraph, sir! You have invented it!"

Professor Henry put up his hand.

"It would be easy to arrange a code of signals. There have been codes in existence for hundreds of years. Savage drumbeats in the jungle and flashing fires from the hilltops. But that is not my affair. I am not an inventor. I am a teacher of natural philosophy. Someone will invent a telegraph. When he does and you gentlemen see it, you can remember that you heard a signal from an electromagnet in Albany Academy in 1831."

2

In 1837, in New York City, Professor Leonard Gale was carrying on the study of batteries. The University of the City of New York, to whose faculty he belonged, had encouraged him. Learning of Joseph Henry's astonishing experiments six years before, the scientists of this dignified university had been put on their mettle by the achievements of the little academy up the river at Albany.

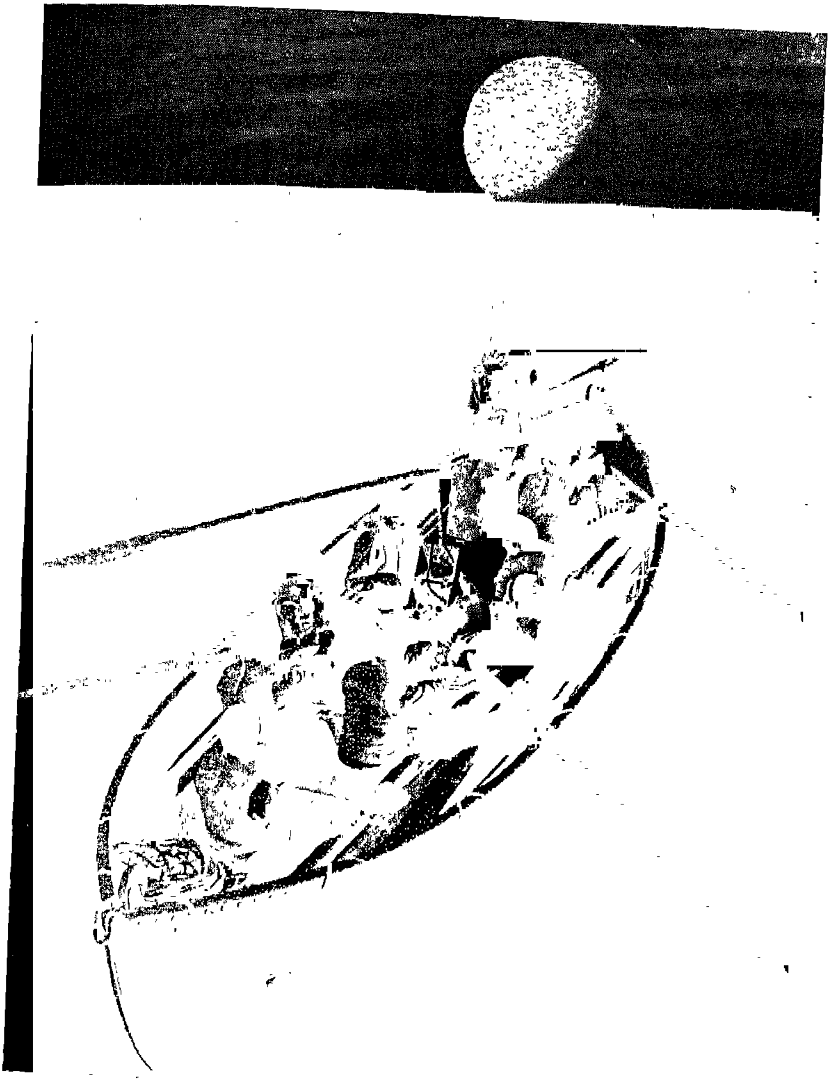
On a chilly afternoon in January of that year, Professor Gale stood near the window of his study, soldering wires to the zinc and copper plates of a new series of cells. His iron cooled before he finished the job and he went back to the fireplace to reheat it. As he waited there, with his back to the fire, a sharp knock came at the door. When he looked up, the door had already opened, and he saw his colleague, the university's professor of "the Literature of the Fine Arts."

He was startled at his friend's look, his pallor, his extreme thinness, the big eyes that seemed set in sockets of bare bone, the mouth that seemed too wide for the chin, the wrinkles that had aged this man too soon.

"Come in, Morse, get warm! You look starved and cold."

"I don't worry about hunger. There are more important things."

Leonard Gale ran his hand over his short, graying beard—a familiar gesture when he was puzzled. He knew well enough that Samuel Morse would go days at a time with scarcely any



Radiomarine Photo

LIFE-SAVING COMMUNICATION

Joseph Henry was fully aware of the possibility of wireless telegraphy. But neither he nor any of the other heroes of the telegraph could have foreseen this open life-boat from which both voice and Morse code can be sent over a thousand miles of lonely ocean. The balloon in the photograph holds aloft a 300-foot antenna.

Acme Photo

TELETYPE

Many inventions were necessary to bring Morse's recording telegraph into practical use. But Morse and his predecessors who had thought of printing signals on paper never conceived of these synchronized typewriting machines. The photograph shows the Western Union room at a political convention. The news is being sent direct to the cities named on the signs.

food. Why? None of them made much money by teaching, but after all there was no reason for a man to starve.

"Yes, yes," Morse said suddenly. "I know what you're thinking. I want you to come to my study and see what I'm spending my money on."

So! The boys had said that Morse's teaching and even his painting had been falling off. There was something then, on his mind, something that ate his substance and brought the fever to his eyes. But Leonard Gale thought these things with half his mind. The other half was on his battery.

"I'm terribly busy, Morse. . . ."

Morse came and put his hands on his shoulders.

"Busy? Busy, man! You don't know what busy means. Why, I haven't slept eight hours in a week. I've got to have advice. You're the only man I know who can give it to me."

Gale could not hold out against the appeal in this strange man's burning eyes and he followed him out the door and down the stairs.

The artist's study presented a contrast to the scientist's. In spite of the cold, there was no fire. The disorder was repugnant to Leonard Gale's scientific mind. But as his eyes moved about over the accumulation of Morse's things, the sense came to him of a man's life broken in two—of a career ended and a new one begun. Round the walls stood the fine canvasses, the sketches, the drawings of one who was said to be the greatest painter in a land which scarcely understood painting. Gale saw these first: then he stared at the rest in shocked unbelief.

"Good Lord, Morse, what have you done!"

On the table, on bookshelves from which the books had been removed, stood bits of whittled wood, glass jars, bent bars of iron, chunks of lead or type metal, bottles of acid, tangles of copper wire. Wires were strung over the room, back and forth over the paintings, over everything. In the center of the table was a large object covered with a cloth. Morse went to it.

"This is my secret, Gale. I must have your promise to help me keep the secret."

He took off the cloth.

A wooden frame stood there. To it were attached the works of an old clock, a long, free pendulum ending in a pencil, a roll of paper. Gale stared at the crude machine without comprehension. Then something drew him closer, and, for a time, his eyes focused on a horseshoe magnet.

It was an old, primitive magnet of the sort designed by William Sturgeon in 1822. The bent bar was varnished and loosely wound with bare wire. The wire was attached to a single galvanic cell. Gale felt a wave of disgust at the amateurish dabbling of this fine painter in an art of which he obviously had learned nothing. He started to speak, but Morse stopped him.

"Stand here and watch this, Gale. Watch it carefully."

Morse went to a corner of the room. Suddenly the crude machine on the table sprang into life. The pendulum moved, the clockwork moved, the roll of paper moved. Gale, bending close over the paper, saw the pencil in the pendulum trace a waving line on the paper.

The machine stopped; Morse came back. His face was transformed. All the pain was gone from it. Now he stood erect, triumphant.

Gale looked away from him to the strange device. His eyes moved from the frame along the wires to the darker corner where he saw another curious contraption.

"Yes," he said. "It is a most promising concept. The recorder, I think, is new."

"But do you realize what I have done, Gale?"

"Of course. If you can carry it out you will fulfill the long dream of the electric telegraph."

"My dream, Gale! My own long dream, mine alone. For four years I have thought of nothing else. Since that voyage from Europe in '32 when the vision came to me. I, a painter, a poor artist, dreamed this thing that has never before entered the consciousness of the greatest men of science."

Gale looked up at him sharply.

"Let's be serious," he said.

"Do you think I would joke with you about a thing like this? Why it is my life, my whole life, the thing God sent me into the world to do!"

"But, Morse . . . think . . . you can't mean you don't know?"

"Know what? I know what I've done!"

"But the work of Franklin, of Arago, of Von Sömmering, of La Place and Ampère, of Schilling and Barlow. Surely you who have given four years to the study of this thing, must know of these experiments."

Morse reached for the table to support himself and his face went gray.

"It's not true," he said.

"But the documents are available. I can't believe you don't know."

Leonard Gale saw then that he must control his temper at this artist's ignorance. Morse's face had gone ugly with his distress as he met the intolerable truth.

"Wait," Gale said. "The work of these men detracts nothing from what you have done. No one can possess a dream alone. No inventor has ever invented the whole of anything. The scientific mind studies every experiment on record. The scientific mind cherishes no lonely dreams. Your mind is the mind of the artist, Morse, it is wholly unscientific. Yet you have made a machine that will write at a distance by electromagnetism. That, I think, is new—not the idea of mere electrical communication. Benjamin Franklin met that idea nearly a hundred years ago. But let's see. How far will this telegraph work?"

Morse was silent for a while.

"That," he said finally, "was what I wanted you for. After forty feet the magnetism diminishes."

Gale detached the horseshoe.

"Obviously," he said. "This is Sturgeon's old magnet. There has been enormous progress in magnets in the last ten years. You must have hundreds of turns of wire."

Morse laughed.

"That shows what you scientists know! Can't you see the fluid will jump—"

"No, no," said Gale. "Insulated wire. Wound with silk. Insulated from itself. Then you must have an intensity battery —a battery of many plates, not just two. I have the battery and I have the wire. Tomorrow we will overcome the distance. Now you must get some sleep and I must get back to my work. You have done a great thing, Morse. It is a magic thing and you must finish it."

A week later, the current ran through half a mile of wire in Morse's study. The machine wrote with a surer movement than it had written with the forty-foot wire. Gale shook his head at Morse's "type" sender, a cumbersome device on which the message to be sent was set in a special kind of type designed to break the current.

"But you can straighten out these things. You need a good mechanic, Morse—a man who can make a workmanlike, finished machine instead of this crude, frail experiment of yours—and you need money."

"And I need you, too, Gale. You have saved my life and my reason. I'll give you an interest in the invention if you'll stay with me until I have got a patent. But tell me something. Where did you learn these things?"

"It has all been written and published. There is a paper by Joseph Henry, the great professor who taught in Albany. He has gone now to the college in Princeton. In the paper, he speaks of Barlow's telegraph."

"But he had no telegraph—this Henry—this professor?"

"I could not say. I will give you his paper."

"I cannot read those papers. But no, he cannot have had my idea. The electromagnet recording telegraph is my idea, mine alone."

Gale smiled.

"I see you have modified your description," he said.

3

William Baxter filed a piece of brass until it was smooth. He held it under the lamp a moment to make sure it satisfied him and laid it on the workbench. Then he looked across at the man who had taken him out of an apprenticeship and made him a full assistant in his important, secret work—a job that, when it was finished, would shake the foundations of the world.

Baxter was only fourteen. But Alfred Vail, the master, was not interested in age.

"I need sure fingers and a brain," he had said. "If a man's got those, I don't care whether he's fourteen or forty. I've watched your work in the big shop, Will. I think you'll qualify."

Vail and Baxter had moved, then, into the upstairs room—the room that was always locked. Directly below it was the big shop of the Speedwell Iron Works, the pride of Morristown, owned and managed by Alfred's father, Judge Stephen Vail. In the Speedwell foundry—the most modern in all New Jersey—had been forged the propeller shaft of the *Savannah,* the first steamship to cross the Atlantic, and now, at the end of 1837, the founders were casting the cylinders for locomotives.

Will Baxter watched his chief awhile, hoping that he would stop work and talk. Alfred Vail had talked to him lately with great frankness, as if they were partners in this enterprise: talked of some of his difficulties with Professor Samuel Morse, the inventor for whom he was making a new machine.

Vail screwed a nut on a bolt and looked up.

"Tired, Will?"

"No. I was trying to remember—"

"*I'm* tired. It's near midnight. I believe I'll shut up shop and go to bed."

"I was trying to remember," Baxter repeated, "how long we've been at this."

"Three months. Seems longer, doesn't it?"

"No. Considering what you've done, it seems less."

Vail thumbed through the notebook that was always on the bench before him.

"It was September second I saw Mr. Morse at the University. Let's sit down, Will, I'm dead on my feet."

Will Baxter pulled himself up on the bench and Vail slumped into the one chair with a sigh of relief.

"Whenever I went to New York," Vail said, "I used to drop in at the University. I love the old place though it never made a minister out of me as I'd hoped. Well, I wouldn't have done the church much good."

It had always amused Will to think of this master mechanic in a pulpit.

"As I was walking through the hall," Vail went on, "a door opened and a man I knew came out. 'Go in there, quick, Vail, and you'll see something.' I went. It was Professor Gale's lecture room. Gale was there and Torrey and Daubeny, professors at the University. And Professor Morse was showing them his telegraph. I thought it was the most wonderful thing I'd ever seen."

"It's more wonderful now," Baxter said.

"All the same I'll never forget the effect it had on me that day. I remember going home to the boardinghouse I stayed in —I was in a kind of daze. I threw myself on the bed and dreamed for a time of the telegraph covering the world. Then I got an atlas and calculated the length of the main American lines."

"And did Mr. Morse ask you that day to work on the machine?"

"Yes. I had known him before. I went up to him after the exhibition and asked if he meant to build long lines immediately.

" 'I need money,' he said. 'Money to engage a mechanic to make a finished machine. And money to get a patent.'

"I told him I had given up the church and had gone into Father's works here. I told him I would like to make his machine myself at my expense. I told him I would also persuade Father to finance him on the patents. But I said that in return for this, he must give me a share of the profits from the invention."

Baxter interrupted. "It must have cost plenty so far."

"It has, and Father's getting impatient. I don't blame him, with the whole country on the verge of financial collapse the way it is. But we can't hurry this thing. Gale, in New York, has only just got a battery that will send the current through ten miles of wire. I don't know what Morse is going to say when he sees his invention here."

"You mean your invention."

"No, Will."

"Aren't you going to patent this lever?"

"I can't patent anything. The contract covers that. Every improvement is a Morse invention."

Will Baxter got down from the bench and went over to where the new, nearly finished recorder stood. He touched the parts and moved them—Vail's lever that moved up and down instead of crosswise, and made dots and dashes instead of a wavy line, the fountain pen replacing the pencil.

Vail got up and walked out.

"Lock up carefully, Will," he said.

The days passed quickly and Professor Morse arrived. Baxter heard his impatient hand on the door latch, and opened the door carefully, peering out. Morse brushed by him without speaking.

"Well, well," he said to Vail. "How's my mechanical assistant?"

Will Baxter's hands tightened.

"I came directly here," Morse went on, "without paying my respects to your father."

Vail put his finger to his lips.

"I don't want you to see him," he said. "He's very upset at the delay. If you give him a chance to speak to you, he may call the whole thing off. People in Morristown have been harassing him for his sinful gamble in what they call 'the telegraph chimera' when the country is on the verge of a financial panic. I've arranged for you to stay at Doctor Cutler's, down the road."

Morse laughed.

"But we will *show* him."

"We can't—yet."

Morse went to the workbench and stared at Vail's instruments.

"So this is the machine you have been maturing in the studio of your brain. You have made changes in my plan."

"Yes. . . . But the general principle is the same."

"But these dots and dashes you have made. I cannot read them with my dictionary. I have worked for months on that dictionary. There are 30,000 words in it. A number for each word."

"Yes, this lever will make dots for the numbers. I thought if you should ever want to make an alphabetical code . . ."

"Yes, yes, I have thought of that too."

Vail turned to Baxter.

"Go out and keep your eye on the Judge, William," he said. "Tell us when he has gone to dinner. Then we can get ours. But we must not meet him."

Baxter went out. For three days, then, Vail and the professor were locked in the shop. Baxter was alone with his thoughts. Like the others, he did not dare meet Judge Vail. At night he would go to the shop to tell Alfred Vail whether the way was clear for them to sneak off to Doctor Cutler's.

On the fourth day, as he passed under the shop window it opened, and Morse called to him.

"Run, boy," he said, "up to the big house. Tell the Judge to come down, we have something to show him. Quick! Tell him it is finished."

Baxter hesitated a moment. Then Vail's face appeared.

"It's done, Will," he said. "It works. We've won."

At the big house, Judge Stephen Vail glared at the breathless boy who had burst, without knocking, into his library.

"I've heard all that before," he said.

"But it's done, sir. Mr. Alfred would not deceive you."

"You mean this thing will transmit an intelligible message

. . . without stopping or stuttering or breaking down?"

He turned his back and stood a long time at his desk.

"I will go, William," he said finally. "But if it fails this time, it is the end."

Judge Vail nodded as he entered the shop, but he gave no greeting to either the professor or his son. Then he asked for a piece of paper, wrote on it and beckoned to Alfred.

"Here is a message. It is for your eyes alone until it is sent. If Mr. Morse can read it from the instrument, I shall be convinced."

Vail took the paper to the corner and set up the lead circuit-breaking types in the groove of the sending instrument.

"Are you ready, Professor Morse?"

Morse, in the opposite corner, bent over Alfred Vail's recorder.

"Ready," he said.

Vail turned the handle that sent the type evenly under the contact lever. Morse started the paper rollers and, suddenly, the long and short clicks were echoing through the room.

Will Baxter watched the Judge. Stephen Vail's face never moved but Baxter saw his hand open and close as the loud clicks echoed through the room. Suddenly the noise stopped.

"Ah!" said the Judge. "Another failure."

But Morse was bending over the strip of paper that he had torn from the recorder. Rapidly he turned the pages of his dictionary.

"I have it," he said. " 'A patient waiter is no loser.' Is that correct, Judge Vail?"

Baxter could not fathom the long silence. Could the Judge still doubt . . . did he, even now, suspect some trick? But then Stephen Vail turned his face away from the room and into the sunlight and Baxter understood and, suddenly, the shop and the benches and the machines and the faces of the three men swam together before his eyes.

4

Joseph Henry opened the door of his study in the College of New Jersey at Princeton.

"Come in, gentlemen," he said. "I am happy to see you."

"We have troubled you a good deal," said Leonard Gale.

"That's what I'm here for, Gale. To share such knowledge as I may have. Well, Mr. Morse, I congratulate you. You must not think, because I don't patent my own discoveries, that I haven't the highest respect for the inventors—the men who use the knowledge that scientists accumulate for the good of mankind."

"It's the inventor," said Gale, "that faces the contempt of the world in a way that we professors of philosophy hardly understand. No one knows what Mr. Morse has been through. His patience, his persistence in the face of poverty and discouragement that would have killed most men, is beyond anything I have ever imagined."

"But now you have won!" said Henry. "The victory is in your hands. Congress has given you an appropriation. That will justify everything."

He turned toward Samuel Morse as he spoke, and was surprised at the failure in his eyes.

"We have not won yet, Mr. Henry," he said slowly. "Congress gave us $30,000. We have spent all but $7,000 on our underground wires. Now they have lost their power in the mud. The insulation hasn't held."

Joseph Henry moved two chairs near his desk.

"Sit down, gentlemen, let us think about it."

For a time, he sat silent with his elbows on the desk, looking out the window across the wintry campus.

"Yes," he said at last. "I was afraid of that. You remember, Mr. Morse, I wrote you about the fluid jumping from wire to wire. There will have to be a good deal of improvement in insulation. At best, it is expensive.

"I've had a good deal of experience sending currents over distances. My most successful experiment was here in Princeton.

"I had a tiny battery here in this study and a wire running from it through the air over to the philosophy lecture hall. This was a distance circuit. Over there, I had a large magnet and a quantity battery. That magnet would support a weight of several hundred pounds. But the magnet was on a separate circuit. I closed that circuit and the magnet held its weight. Then I closed this circuit over here. That sent the electrical fluid through the long wire to the lecture hall where it deflected a needle. The needle opened the second circuit and caused the magnet to drop its weight. The boys were astonished at the power of it. It was a kind of relay."

"I invented the relay," said Morse.

Henry frowned a little.

"Several people have invented it," he said. "But the point I was coming to was the point about the overhead wire. I used a bare wire, of course."

"Yes, yes," said Morse. "In the original caveat of my invention, I wrote of suspending wires from posts. But Vail—my mechanical assistant—and I both agreed that it was dangerous. The wires might come together in the wind, people might tamper with it. We decided—"

Henry put out his hand to interrupt.

"I said wire, Mr. Morse, not wires."

Morse stared at him.

"I beg your pardon, sir?"

"I used a single wire. The ends were sunk deep in wells."

"But the circuit, Professor, what makes the circuit?"

"The ground. The earth. The earth will act for you as one wire if you bury the ends of your other wire in it."

"You mean the fluid will flow—"

"Through the ground? Certainly."

"When did you make this discovery, Professor Henry?"

"I didn't. It was made in Germany by Steinheil. It isn't patented. You are at liberty to use it. An inventor must borrow such things, whoever discovers them."

Leonard Gale was leaning forward in his chair, his near-sighted eyes straining behind his spectacles.

"Good Lord, Morse, that is the answer," he said. "No more digging! Why we can do it with what we've got left! No insulation—"

Henry stopped him on the word.

"Insulation, yes. Insulation where you fasten the wire to the poles. I suggest you come in later and talk about *that*. I have some ideas. If you will show me your plans, I shall be glad to give you my opinion."

"If it works," said Morse.

"It cannot help working," said Joseph Henry.

Samuel Morse sat for a long time with his face buried in his hands. Then he jumped to his feet.

"If it works we will win!" he said.

"If it works, we shall be forever indebted to Professor Henry," said Leonard Gale.

Morse, who had picked up his hat and started for the door, came back.

"Forgive me, Professor," he said. "You must know of my respect for you—my deep veneration. Ever since we first met in Chilton's chemical store in New York—seven years ago, sir, it was, in '37—I have realized the great importance of your discoveries to the telegraph. And I shall see that the world, too, knows of my debt to you."

They went, then, and Joseph Henry, in the quiet of his study, thought back over the years. He remembered the brilliant boy, Edward Dickerson who, in his freshman year, had been so astonished at the experiment in which a battery made of dressmakers' pins in drops of acid had communicated a release to the great magnet and let drop the weight of hundreds of pounds. He remembered his lecture in which he had said, "By such a device, gentlemen, you could ring church bells hundreds of miles away," and how Dickerson had come to him afterward and urged him to patent his discovery. He had made rather a pompous little speech to Dickerson—what was it?

"I have not considered it compatible with the dignity of science to confine the benefits which might be derived from it to the exclusive use of any individual."

Joseph Henry smiled at the memory.

"Well," he thought, "perhaps, after all, I was too fastidious."

5

Alfred Vail walked up and down in the Mont Clare railroad station at Baltimore. The eight o'clock train had come and gone—twenty minutes late—with its tremendous noise and clouds of smoke, sparks and flame pouring from the enormous stack of its wood-burning locomotive. As it had come, Vail had sat by his instrument, bent over the recorder in case a message came through and, in the noise, he would fail to hear the click. Now it was quiet in the little station; the wagons had driven away and all the crowd, come for the great event of the train, had gone.

Alfred Vail, as he waited, thought back over the years. Today, the 24th of May, 1844, it was six years, eight months and three weeks, since the day he had stumbled on Professor Morse and his crude, homemade recorder in the University. The instrument now on the table before him bore little resemblance to the old frame with its wavy pendulum. This one was small, compact—its parts moved with a quick, staccato motion. The rolls of paper were still there, but the point that marked them was no longer a pencil or pen; it was a stylus which indented or embossed the paper. The stylus striking the paper made a very definite sound, and Vail had discovered, lately, that he could get the message simply from the sound, *without even looking at the paper.*

Several times he had thought:

"How would it be, to make a machine without any paper rolls, but with a piece of hollow metal for the stylus to hit so the click would be louder. A 'sounder' instead of a recorder?"

Alfred Vail was always thinking, "How would it be?" He thought it several times a day and sometimes said it aloud to himself. Each time the thought came, he would go to his drawing board and sketch it, then draw it out carefully. He had accumulated hundreds of these sketches and drawings. He wondered how, after all, he could ever profit from them. His contract was clear enough, that every telegraph invention must become a Morse patent. "Of course," Morse would say to his friends, "my mechanical assistant is a help to me." But lately, since so much praise had come to him, he had said it less often. Mechanical assistant! How Vail loathed the expression! "Oh, yes, let me introduce my mechanical assistant, Mr. Vail."

Vail had finally persuaded him to throw away the old "correspondent" as he called it, the cumbersome sender with its circuit-breaking line of type. Now, beside the recorder on the table was a neat key of spring steel: you pressed it to make the contact and then released it. Now, today, Professor Morse, in the Supreme Court at Washington, would use Vail's key.

Vail counted on his fingers the changes he had made. The type was gone with the roller to move it. The transverse lever on the recorder was gone and the wavy line was now a succession of dots and dashes. The horseshoe magnet was gone and there was a neat spool instead. The pencil was gone. The rolls of paper and their clockwork were still there, but Vail knew that no commercial operator would use them—the sound was so clear.

The door opened and the stationmaster put in his head.

"There's some distinguished citizens here," he said.

"What of it?" said Vail.

"They say if a message comes through from Washington they want to see it."

"They can come in, then, if they keep quiet."

Ten men and a boy filed into the room.

"I wanted my boy to see it."

"Is that it, that little thing on the table?"

"Any danger of it exploding?"

"Is it true that you can send parcels over the wires?"

The machine on the table clicked and the men drew back, afraid. Vail put his finger to his lips.

"Quiet, please. That is the signal. Now the message will come from Washington."

Vail turned his back to the machine and held up his hand. The machine jumped to life behind him, the clockwork whirred, there was a short, hard click and then the longer sound that meant a dash, repeated twice.

"W," said Vail. "H . . . A . . . T." The sound stopped and Vail could hear the varied breathing of the men. It seemed to him that an hour passed before the clicks came again—four sharp dots.

"H," said Vail. "A . . . T . . . H . . ."

When the pauses came between the words Vail was sure the system had broken—they were so long. Three times the fancies chased each other through his brain: battery failure, a broken wire, a jammed lever. But the longer, last word came through finally, and he could feel the sweat running down his back and the queer chill running up to the roots of his hair.

"I guess that's all, gentlemen."

"I lost it," said the boy.

"Hush, lad, it's a miracle."

"I have it . . . 'What hath God wrought.' "

The men saw the light in Vail's face and lowered their eyes. He stood a moment, facing them in the quiet, and then turned back to the table, put his finger on the key and ticked the eighteen letters back to the capital of the United States. When he had finished, his hand dropped to his side and behind him a flood of talk began. He could not hear the questions.

"God . . ." he was thinking. "Yes, I guess that's so. Franklin, Sturgeon, Henry, Steinheil, Alfred Vail and the strange artist, Morse. And God, keeping us at it."

5

BEHIND BESSEMER

I

OUT IN THE WESTERN FRINGE OF THE AMERICAN COLONIES, two rivers crept round a hill to form a third, largest of them all. Where they met, there was a flat point of land below the hill and here, in 1754, a young surveyor named Washington was struck by the magnificence of this joining of great streams and, being a practical man, was more particularly struck by the military value of the spot on which he stood. It is not surprising that he wrote in his journal that he thought "the land in the fork . . . extremely well situated for a fort, as it has the absolute command of both rivers."

The fort was built; round it grew a trading post, the trading post became a city and the city became the gateway of the West. From Fort Pitt, the city took the name of Pittsburgh and the river born there was the Ohio; down it to the Mississippi floated the thousands of flatboats which began the settlement of Kentucky and the Mississippi Valley. Pittsburgh was the far outpost of civilization, the meeting place of the settled East and the western wilderness, the jumping-off place of restless men and women tired of cities and taxes, poverty and laws; people who wanted to make a new world.

It is no wonder Pittsburgh became a center of business, a market of supplies for the settlers, and later, when boats were invented which could go against the current, a market for the settlers' farms. Then iron was found in the western Allegheny foothills and Pittsburgh became the cradle of steel; the steel flowed out until it stretched to the Pacific and made a new nation, gigantic, steel-boned and indestructible.

In 1811, the first steamboat of the West was launched in Pittsburgh by Nicholas Roosevelt, its builder, and under his command ran down the Ohio to the Mississippi and down the Mississippi to New Orleans and back, leading the march of civilization into the middle valley of the continent. In that same year, an Irish family living on Front Street, a family prosperous from a quick business in Pittsburgh real estate was cheered by the addition of a son. It was an inspiriting time to be born. It seemed as if the whole of the new world lay in the lap of every baby who arrived in 1811.

In his childhood, William Kelly wandered free and unafraid in the rough Pittsburgh streets. He knew his way among the docks where the new, smoky river boats began and ended their long journeys. He was familiar with the wild language and gambling ways of boatmen and traders, men accustomed to stake fortunes on any westward venture. He saw families with stern-faced women and staring children who had left everything which could be called home to face years of wandering in an unknown world. He saw them herd their cattle onto the old flatboats—still more spacious and, to many minds, less dangerous than the new smoking monsters. Bill Kelly saw these things, but his eyes were mainly on the high stacks of the steamers, the "walking" beams of the engines, the iron and copper or brass of the machinery.

When he was not along the wharves, he was watching the blast furnaces against the hills. Before he was ten, he could describe the iron process: the mingling of charcoal and ore in the stack, the fierce heat of the burning, the two streams of hot, thick liquid that flowed out at the bottom, the slag and the iron. The molten iron ran through channels called "sows" into molds known as "pigs" because they seemed to be suckling the "sows" in their sand beds. He knew the use of the pigs when they had cooled; how, when they were remelted, there came a surprising point where they turned from liquid into paste—no matter how intense the heat—as if they had cooled in the hottest fire and he knew the paste was "wrought iron," pure, malleable; that it could be taken out, forged into the shapes of horseshoes, axles, and gun barrels, or drawn at last into fine wire. And he knew further that such iron, heated in powdered charcoal, hammered again on the anvil and tempered, sometimes became the toughest steel, though how this came about was a mystery to most people. It was still magic and it was expensive.

School, and the primitive college which Bill Kelly's ambitious father insisted upon, taught him something—not a great deal—of carbon and oxygen. Iron ore was rust, a compound of iron and oxygen, plus what were called impurities: carbon, silicon, manganese, sometimes sulphur and other matters to be got rid of. The lime or "flux," which was mixed with the ore and the charcoal, combined chemically with these things to form the slag, which, being lighter than the iron, floated on top of it and so could be drawn off separately.

But some carbon remained always in the molten iron. That was the crux of the whole business. That was what made cast iron—pigs, pots, firebacks, stove parts, anything that was made in molds from the liquid iron from the blast furnaces. A sharp blow with a hammer on the side or belly of a cast-iron stove would shatter it. To get malleable iron, soft enough to hammer and work, still more carbon must be removed by melting cast iron again and stirring it (called "puddling"), but as the carbon went out, the liquid iron seemed to cool; it grew stiff and could not be cast in molds.

Young Kelly had heard the iron men say, as the reheated pigs melted and then stiffened, that the iron was "coming to nature." That meant that carbon had left it. The hammering of that stiffened iron got still more carbon out of it and it became useful as soft wrought iron which could be rolled into rails or machine parts. But to make it into steel which was both tough and resilient, a little more carbon must be put back into it by reheating it in powdered charcoal.

It is obvious to anyone who looks at this expensive, backhanded process, that there must be a point somewhere at which the cast iron becomes steel before it is wrought iron, and that even the wrought iron must become somewhat malleable before it "comes to nature." But no one in 1830 when William was nineteen, had solved this Chinese puzzle.

The puzzle must have kept him awake a good many nights. But then, when he graduated, there occurred one of those curious switches which men in their formative years so often encounter which seemed to turn him forever away from the furnaces.

His father had gone on prospering. He had become a highly respected citizen. His older son, John, had a respectable position as a partner in a wholesale dry goods firm. Mr. Kelly wanted the college-educated William to have a job worthy of his training.

The smoke from furnaces, rolling mills and factories using steam engines already hung thick and low over the city. Perhaps this cloud which shut out the sun had depressed the higher-minded citizens into a sense that the origin of such blackness must be disreputable, morally unclean, at least undesirable for a college graduate's attention. Whatever Mr. Kelly thought about it, the fact is that William, on the threshold of maturity, was persuaded to join his brother, John.

To us, in the midst of machines and technological power, the spectacle of a man turning from the beautiful, mystic study of metallurgy to the handling of dress materials is anything but inspiring. But in the 1830's, when most Americans were farmers, when pioneers were moving down the Ohio to establish great agricultural communities, clothes were an important necessity. The days of home spinning and weaving were over. Cloth was pouring out of the Massachusetts and Rhode Island textile mills. A man who sold cloth in Pittsburgh was an important citizen, likely to make money immediately, while a man who made iron was gambling on the future.

William stayed with his brother until he was thirty-five. His life was unlike the life of an Eastern merchant. As salesman, he made long, difficult journeys with his samples. On the big river steamboats he was a familiar figure, and the people of the settlements which now had grown into towns, welcomed him.

One day, during a sojourn at Nashville, the friends he stopped with invited him, by way of entertainment, to the graduation exercises of a girl's school, known as a "female academy." This does not strike us as an irresistible evening's amusement, but Nashville, in the 1840's, was not precisely a pleasure resort and the event was important. Female academies in the West were rare and admired institutions.

William, watching the exercises, concentrated especially on a lovely girl who spoke her piece in a provocative southern voice. When the evening was over, he was reluctant to go back to Pittsburgh. He talked a long time to the girl's father and Mr. Gracy ended by inviting him to Eddyville, Kentucky, where the family lived.

William Kelly, at thirty-five, must have looked younger. His handsome face, weathered but not aged by his travel in the open, was vigorous and spirited. His high, broad forehead, his steady blue eyes suggested mental power. Mr. Gracy was impressed by these things and, though Mildred was only sixteen, could not help feeling that Kelly, with his honesty, his health and his fine prospects, would make her a better husband than any of the village boys.

So William was hospitably received in Eddyville. He pursued his courtship, probably taking long walks with Mildred in the woods about her home. The fact about these walks, however, which has come down in history, has less to do with Mildred than with the pieces of red hematite which, as he walked, William Kelly was continually scuffing up from the ground.

We may imagine him stopping, picking them up, looking about him at the woods, heavy with potential charcoal, and his first, greatest love coming back to him.

"But I must tell John of this," he would say. "He must come and see this; he would forget the dry goods overnight!"

"See what?" asked Mildred.

"That here in my two hands, lies an infinite fortune."

No doubt the girl's eyes clouded then with thinking that her man cared more for the iron ore than for her, and if, at that moment, he had looked at her he might have seen the shadow which was to darken years of his life.

2

About a year later, in 1847, the Kelly brothers stood before a furnace of the sort that was used for a "finery fire." In such furnaces, iron makers used to melt pig iron between layers of charcoal and stir it until it came to nature as soft, workable iron.

"Watch this carefully, John," said William, "and see if you see what I saw. If you do—if it's true—then my idea will save us."

The Kellys had bought fourteen thousand acres of Kentucky land and some furnaces and equipment belonging to other adventurers. It had seemed an infallible project with so much ore lying on the surface of the ground and a vein underneath, easy to mine with a little digging. But the furnaces had made quick inroads on the surface hematite. Excellent iron had been produced and sold and the Kellys had paid up a part of their investment. Then they had made a shocking discovery that the vein beneath the surface was a wholly different and inferior quality of ore, so bad that it would not pay to mine it. The fact was that the surface ore had acquired its goodness through long exposure to the air.

The Kellys had explored, then, their whole fourteen thousand acres looking for other iron. They had found it at last, a good vein, but in cleared land so far away from the woods that the cost of hauling either the ore or the charcoal fuel would have ruined them. So the brothers, after buying the land and some furnaces and building others, after establishing the Suwanee Iron works, hiring forgemen and putting some three hundred Negro slaves to work, faced the threat of failure.

It was at the deepest moment of their discouragement that William had seen the vision in the fire that kept him awake half the night and in the other half gave him some startling and extremely chemical dreams.

The brothers stood silent now, watching the charcoal glow red between the pigs, saw the charcoal burn away and the pigs melt down. The little engine that worked the blower was puffing away.

"See," said William. "The air from the blast is oxygen. It combines with the carbon of the charcoal to form carbonic acid gas which rises, invisible. That chemical combination produces heat."

A forgeman named Jeremiah Tiley who stood behind the Kellys frowned. William Kelly's talk disturbed him. Tiley could not read or write. Whenever he heard words like "carbon," "oxygen," "chemical combination," he frowned. It was this crazy chemistry that was ruining the iron business.

"We'll be needing more charcoal," he said.

"That's just what I'm going to show you we *don't* need," said William. "There, look!"

He pointed to the bubbling molten pig iron.

"More blast," he said. "More air. Get the engine going faster."

"It'll be cold air," said the forgeman.

"Yes. More and more cold air! Watch it now, John. The charcoal is burned out. Watch where the blast bubbles up. See, it's changing color! It's getting hotter. The cold air is making it hotter. See the sparks fly off it."

Tiley came back from the engine.

"That's funny," he said. "Looks like it was coming to nature, yet it's still a melt."

"Get a ladle. . . . Pour a little here in the sand. . . . Now, pick up that ball of iron before it cools any more; put it on the anvil."

Tiley, who had been a blacksmith, struck the glowing ball with a hammer.

"Good Lord!" he said. "It's soft!"

"Do you see, John? We've made malleable iron without fuel. With nothing but air. We won't need any more charcoal now."

The forgeman hammered the iron flat.

"It ain't possible," he said.

"Yet you've seen it with your own eyes."

"There's some trick. It ain't reasonable. It'll be bad iron. It's some crazy magic."

But the Kellys did not hear him. They were talking excitedly in short, sharp words.

"It's over my head, Bill," John said at last. "But I've got more faith in you than in all the iron masters in Pennsylvania."

Jeremiah Tiley was walking away.

"It'll cost me my job," he said to himself as he turned the flat iron disk over and over. "Me and hundreds of others."

3

William Kelly's young wife looked at him long and steadily. She had sent the house servant out of the room.

"Look at me, Will," she said.

William Kelly looked up and was surprised at the distress in his wife's eyes.

"What is it, Mildred? What's wrong?"

"See," she said gently, as if she spoke to a child. She lifted her coffee cup. "See, I blow on my coffee to cool it."

"Well, what of it?"

"I'm trying to make you understand what people are saying about you. Can't you see? You keep telling everyone that you blow on melted iron to make it hotter. Truly, it's not sensible!"

"No, it's not, Mildred. Not as long as people go on thinking that coffee and iron are identical substances. If you froze that cup of coffee it would be ice. It would then be in the same physical state as iron before it's melted. Now if you think that lump of ice is identical with a lump of iron, and if you go round telling people that, they'll give you queerer looks than they're giving me."

"I don't know what you're talking about," Mildred said. "I only know that every Kentucky iron master says that a cold blast will cool hot iron. If you heat a poker red hot and put it in the wind, will it get hotter?"

"I thought I'd explained that," said William.

Mildred's eyes never left his face.

"You've been working too hard, Will," she said. "You never rest. You never sleep. I love you, Will, and I want you to keep well. You're losing your health."

"Why don't you say what you mean? What you mean is—"

"Don't! Will! Don't!"

For an instant he saw the terror in her eyes. Then she covered her face with her hands and sobbed desperately.

4

"If you had a microscope powerful enough," said William Kelly, drawing on a piece of paper as he spoke, "and if you could look through it at a piece of cast iron, I think it would look like this."

He passed the paper to Doctor Higgins; then he got up and looked over his shoulder.

"Those black marks are little bits of carbon," he said. "Now charcoal is, as you know, pure carbon. So you might say that cast iron has microscopic pieces of carbon all through it. Good. You melt the iron. If you could magnify the molten mass, it would look like the inside of a blast furnace, bits of iron and charcoal mixed together. Well, you blow into a blast furnace to make the charcoal hotter. So why not blow into liquid iron to make the bits of carbon in the iron hotter? Oxygen and carbon will always unite and in uniting, heat is produced. As they unite here when the cold blast goes through the liquid, the carbon, as we say, burns; actually it turns into carbonic acid gas and passes off into the air. That turns the cast iron into steel or malleable iron, depending on when you stop the blast—depending on how much carbon has gone out. And you've used no fuel except what is contained in the iron—no fuel except air which costs nothing."

Doctor Higgins did not speak. He kept looking at the paper. Then he shuffled the other rough drawings Kelly had given him: drawings of blast furnaces, sketches of new finery furnaces. Suddenly he jumped to his feet and stood facing William Kelly.

"Crazy!" he shouted. "Crazy! Insane! My God, is the whole world crazy?"

"Wait, Doctor, wait! Don't speak to them yet. . . ."

"I'll wait for nothing."

He threw open the door, surprising Mildred and her father who sat silent in the next room, waiting for the terrible verdict.

"So," he said. "I've seen your patient, Mr. Gracy."

Gracy and his daughter stood up.

"Mr. Gracy," the doctor went on. "You've asked me to diagnose this man's trouble—his mental trouble. Well, I'll tell you. His trouble is genius, that's what it is. And if every man in Kentucky had one hundredth part of the brains and sanity and ingenuity of Mr. Kelly we'd have a state to be proud of. Yes, yes, I know about the cold blast and all the rest of it. And if I had any money, I'd put every last penny of it on this process. And mark my words, whichever of you has an investment in it now will be rich one day—a millionaire. Well, that's my verdict, sir. If he's crazy, then I wish I was a half-wit."

In the time that followed, William Kelly went more quietly about his business. He controlled the impulses of frank enthusiasm that had made him tell his ideas to anyone who would listen. Most of his time now appeared to be devoted to a new blast furnace. Yet the malleable iron never left his mind. A few of his doubting forgemen changed their minds. He took on two English iron workers who applied for the job. He and the Englishmen and Doctor Higgins who, in these days spent much time with him, worked at odd hours on the new "air boiling" furnace which used no charcoal. Presently a second doctor, named Champion, joined them, fascinated by the process that seemed to him so like "decarbonizing blood in the human lungs." And William Kelly made many things from the malleable iron, such as sugar kettles which were shipped to Louisiana plantations. And he made iron for boiler plates for the river steamers which was sold up in Cincinnati.

The sale of these things made money for him. He was still in debt, but his payments quieted the gossips. And John, who had entire faith, had gone back to Pittsburgh to wind up the dry goods business. Then, from outside, came the hardest blow of all.

News traveled slowly in the 1840's. There was no telegraph, and in Kentucky and Ohio even the mails were uncertain and took a long time. News spread mainly through the gossip of the passengers and the captains of the river steamers. So it was a year or more before the tales of the Kelly process reached the world outside Eddyville.

Then one day, a visitor announced himself at the Kelly company office, demanding to see Mr. Kelly in person.

"I've got a load of iron for you," he said to William.

"I don't need any iron."

"Well, we don't need it either. I'm with Shreve, Steele and Company, Cincinnati. It's your last shipment of ingots. Made

Jones & Laughlin Steel Corporation

Newman-Schmidt Studios

CRADLE OF STEEL

Here is Pittsburgh where William Kelly found more inspiration in smoke and flame, iron and carbon, than in the clean gentility of cotton cloth. From the scattered groups of furnaces and forges that Kelly knew, the city has grown to the enormous industrial proportions shown in the photograph in little more than a century.

Acme Photo

THE FORGE MAN'S FEAR

"It'll cost me my job," he said. . . . Note that only one man appears in this photograph of a modern automatic strip mill for making sheet steel. When this magnificent invention came into use, it is said to have sent 80,000 steelworkers looking for other jobs. Where is the social inventor who should be finding useful work for men released from back-breaking manual labor?

by your new-fangled process. And you needn't send any more."

"Is there anything the matter with them?"

"I don't know. That ain't the point. The point is we're a conservative firm. And the iron for our mills is going to be made the old way or not at all."

"But your new boiler plates made from this iron are better."

"How do we know that?"

"Have your boilers burst?"

"Not yet, they haven't. But we're taking no risks. So it's the old way or we don't buy them."

"But I've got my process working now so that I can reduce the price."

"Price ain't the point. It's quality. We've heard about this pneumatic iron and we don't like it. And pretty soon you'll find your other customers returning their goods too. So I came here myself to see that your process goes out of business before you sell us any more iron. And mind you, if you cheat, we have ways of finding out."

So William Kelly told his workers that the iron must be made the old way from wrought iron that had "come to nature" in the finery furnace, and some of the men congratulated him on coming back to sanity and privately congratulated themselves that the air-blowing process was finished and that their jobs and the jobs of forgemen everywhere were forever safe from iron that needed no forging.

But William Kelly went deep into the woods and built himself a new furnace and there, secretly, he and Doctor Higgins and the Englishmen who believed that cold air would make iron hotter made experiment after experiment. There were still difficulties in the process. Usually, the molten malleable iron was of good quality, if the right kind of ore was used. But to get high quality steel, guesswork was still necessary, and neither Kelly nor the doctor nor the Englishmen could ever be quite sure of the exact moment at which the blast should be cut off to keep precisely the right amount of carbon in the hot liquid.

With these experiments and with his other unprofitable work, some five years went by. In the course of those years, he built seven different "converters." The only incident which brought any diversion in that time was the sudden disappearance of the Englishmen. They simply vanished one night without a word and without collecting the wages due them, and, though Kelly was able to trace them to the coast where they seemed to have taken a steamer for England, he never saw them or heard from them again. The mystery disturbed him for a while, but as the men had stolen nothing—as, indeed, they had not troubled to ask for the money he owed them—he presently forgot about it.

Then one day in 1856, Doctor Higgins brought him the news that a patent on the pneumatic process had been issued to a man named Bessemer.

"Are you sure it is the same?" asked Kelly.

"It is identical. Here's the article about it in the *Scientific American* for September 13th."

"Well, perhaps he's entitled to it. Some Pittsburgh man, I suppose."

"No. He is not even an American."

"Not an American! A foreigner claiming the credit for an American invention?"

He took the little twelve-page magazine from the doctor.

"Ah!" he said. "He claims 1855 for his date. When did we start?"

"Let me see, was it '47?"

"The process was making iron for sale in '51. I don't need to go back of that."

"I wish you'd got a patent, Kelly. I know you didn't want to apply till you were satisfied that you'd got by all the snags. You were too scrupulous, maybe. Well, it's not too late, if we can afford to get a lawyer. You can get a patent interference."

"Hum," said William, still reading. "It's a Londoner, is it! Bessemer. He's got the Royal Institution behind him. Look, this article quotes the London *Times*. Even they don't believe it. Listen to this. 'The account of this discovery really appears something more like an Oriental tale than the description of a solid, sober invention.' Well, it's a sober invention all right, but it was made in the U. S. A. So I'll go on record now."

He went to his desk and took up his pen.

"Messrs. Editors," he wrote. "In November, 1851, I commenced a series of experiments with view of converting fluid pig metal into malleable iron, with a strong blast of air, and without the use of fuel . . ."

He wrote fast, describing the details of his process.

"My experiments were conducted publicly at this establishment . . . the subject was discussed amongst the iron masters, etc., of this section . . ."

"It was certainly discussed," said Doctor Higgins, reading over Kelly's shoulder.

"I have reason to believe," he saw Kelly write, "my discovery was known in England three or four years ago, as a number of

English puddlers visited this country to see my new process. Several of them have since returned to England . . ."

"Good Lord!" said the doctor. "I never thought of that."

"I'm only writing," said William Kelly, looking up, "I'm only writing for the record."

5

Around the new furnaces of the Great Cambria Iron Works at Johnstown, Pennsylvania, were grouped a hundred or more men. It was the summer of 1858. An important experiment was in progress. Its success or failure seemed vital to the workers who were there to watch it. If it succeeded, many of them would find themselves unemployed.

But today the crowd was jubilant. Last week there had been a spectacular failure. The tremendous blast from the new Cambria engine had blown the whole contents of the new Kelly "converter" into the sky. So the men were in a holiday mood, ready for more of "Kelly's fireworks."

"We're having Fourth of July every week this summer," said one of the forge workers.

"Or Saint Patrick's Day," said another. "It's hard to tell which it is."

In front of the men stood Daniel J. Morell of the Cambria firm. Beside him was William Kelly.

"If it is successful," said Morell, "Eben Ward and I and some other iron men will form a company based on your patent. 'The Kelly Pneumatic Process Company.' How's that? With the right kind of furnace we can make steel."

"Steel . . ." said Kelly, slowly drawing out the word. "Well, that's what this man Bessemer claimed with my process. But steel is tricky. Malleable iron is sure."

Morell laughed.

"Neither Bessemer nor you can be sure of steel by your process," he said. "But I want to talk to you about that later. First, we've got to prove the converter."

"It can't fail."

"It failed once."

"That was not a failure of the process. It was a mistake in detail."

"I have faith in you, Kelly."

Many people, William thought, had shown faith since he had got his patent over Bessemer. The decision of the Commissioner of Patents had come through when everything in the world had seemed to be lost. The panic of '57 had dropped like a bomb on the country. The Kellys had lost everything. The Suwanee works had been closed.

Then the decision was published. William Kelly knew the words of it by heart.

"Priority of invention in this case," the end of it said, "is awarded to said Kelly, and it is ordered that a patent be issued accordingly. . . ."

Mildred had come to him in tears.

"Forgive me, Will! How could I have doubted you?"

"They are calling you a 'genius' in the town," Doctor Higgins had told him. "As if they had invented the word."

And then Daniel Morell had said if Kelly would come to Johnstown he would turn over part of the Cambria Works to his experiments.

All this came back to Kelly in a quick flash of memory as he stood now near the blast-engine room of the Cambria blast furnace. Outside the door stood his latest converter, an iron boiler section lined with firebrick.

Suddenly a little car holding a ladle was hauled over a track from the foundry. It stopped at the converter and from it five hundred pounds of molten pig metal were poured into the converter. Kelly turned the elbow of a pipe from the engine down into the converter, and gave the signal for the beginning of the blow.

Now the sparks rose into the air. Kelly knew that, along with the carbon, the silicon and the manganese, there were sparks of iron, too. But today the blast was controlled and not too much iron would be lost.

As the crowd of workers jeered and laughed, he ran about picking up the sparks of iron that had landed on the ground. With tongs, he took them, glowing, to the anvil. With a hammer he shattered them. The men began to yell.

"There's one over here, Kelly!"

"Don't forget this one."

"Here's a spark you missed. I'll bet it will flatten fine. Ha, ha! The Irish fireworks again!"

But William Kelly knew that the time would come when enough carbon would be gone from the iron to produce a spark that would not crush under the hammer. Suddenly he found it, found another—and held up his hand.

"Ready," he said. "Ladle it out."

Instantly men came with long ladles and puddlers and tongs, and brought lumps of the cooling metal to the anvil. One after another, by man after man, the pure, soft balls of iron were flattened out.

Then a slow, angry roar began among the crowd of workers.

"Their jobs!" said Morell. "A few years from now, there'll be a job for every man in the U. S. A. who ever worked a piece of iron. But they don't know that. Well, come along, Kelly, before they kill you. I want to talk to you."

In the office of the Cambria Iron Works that afternoon, Daniel Morell explained what was on his mind.

"Steel," he began. "Steel—cast in ingots, ready for the rolling mill, to make rails, plates and bars. That's what we want—cheap steel—and we'll get it. I know your doubts about steel. But I have learned something you don't know.

"Neither you nor Bessemer could make steel by your process and be sure of its quality. But another Englishman—a Scot, rather—named Robert Mushet has made another discovery. He has found an ore he calls 'spiegeleisen' which, added to your pure iron, made by your process and Bessemer's, will make true steel."

"So!" said Kelly. "The ore has carbon in it? It's the old business then of taking the carbon out and then putting it back!"

"Carbon and manganese and silicon, Kelly. In exactly the right proportions. There won't be any more guesswork about the quality."

"Is there a Mushet patent?"

"Yes. And Ward and I mean to get it. We'll have to pay royalties to you and Mushet both, but it'll be worth it. They say the Mushet trick is infallible."

6

The next six years saw the birth of the steel industry in the United States. In thirty years more, America would lead the world in steel production. Another half century after that, steel would help save American democracy.

But those six years from '58 to '64 were full of strange happenings.

Bessemer, in England, had gone on. The American patent for his process had been turned into wastepaper by the Commissioner's decision. But he had been able to patent his *machines* for use in the process. His converter was a beautiful, balanced vessel hung from a crane. When it was tilted, the blast was automatically cut off.

In 1863, two Americans went to England. One was Zoheth Sherman Durfee of the Kelly Process Company of Wyandotte, Michigan. The other was Alexander Lyman Holley of the Bessemer Steel Company of Troy, New York. Both brought back patent rights. Durfee brought Mushet's spiegeleisen. Holley brought the rights to the Bessemer machinery.

In 1864, the Kelly Process Company turned out the first commercial steel ever made in America by the pneumatic process. A year later what was called Bessemer steel was made by the same process in Troy. Then agents from the two companies visited each other's works. What they both saw was startling, to say the least.

The Troy man saw steel made in Wyandotte with machinery which looked like that covered by the Bessemer patents to which the Kelly Process Company had no legal right. The

Wyandotte man saw Mushet spiegeleisen, to which Holley had no right, being poured into Troy steel. He also saw the Kelly process, which the Wyandotte men controlled, running at Troy, literally at full blast!

When these facts came out it seemed as if both works would have to shut down. Morell, Ward and Durfee said they could not make profitable steel unless their converters looked like Bessemer's. Holley obviously could make no steel at all without cold air and spiegeleisen. So the two companies got together.

They got together in a conference in 1866 and there occurred one of the strangest bits of patent horse-trading in the history of American invention. The conference decided to merge the companies, issue stock, give seventy shares to the Bessemer people who only held one patent, and thirty to the Kelly Process Company who held two. And on top of this, it was decided to suppress the name of Kelly and call all steel, made by the pneumatic process, Bessemer steel!

This deal remained a mystery to William Kelly to the end of his life. And it has remained a mystery to many others ever since.

Yet there is a possible answer to part of it. The main use for steel in the 1860's was for railroad rails. True steel rails were made in England from Bessemer-made steel and sold in the United States as "Bessemer rails." When they were used to replace iron rails, they were so superior that there was immense demand and immense publicity. The name Bessemer was the name on everyone's lips when steel was mentioned. Perhaps, for this reason, the name of Kelly was dropped. As Kelly had sold the control of his rights he could do nothing about it.

But by 1866, William Kelly had left steel men to work out their own destinies and gone to live with his wife and family in Louisville. The great Civil War was over and the torn border state of Kentucky was quiet again after the terror of the conflict.

In the long evening of his life, William Kelly learned peace of mind in spite of injustice. He spent many hours reading and studying the mysteries of science—more rational than the mysteries of human conduct.

Between Mildred Kelly and her children there was a story often told. But if William came in while they were telling it, they would stop.

"You were too young to remember," Mildred told her son. "But your father had two English puddlers working with him in Eddyville. After they disappeared we forgot about them until your father learned of the English patent.

"Then one night, Mr. Durfee showed us a portrait of Henry Bessemer. It was unmistakable."

"Photographs are deceptive, Mother," said her son.

"Not this one. But your father would not make any statement he could not prove. He has made me promise never to mention this outside the family."

But William junior mentioned it thirty-five years after his father's death in a public address, when a bronze tablet was unveiled in Wyandotte to William Kelly's memory. It made a stir, for a time, in the English and American papers. English steel men wrote that Bessemer had never been in America. Neither Bessemer's alibi nor the Kelly family legend was ever fully proved. Eventually both were forgotten for, in time, the open hearth largely replaced the pneumatic converter in America.

7

In the long sweep of the history of invention, such mysteries are not important. It has happened again and again that two or more inventors in separate corners of the world have independently made the same invention at almost the same moment. It is the judgment of sober historians that Bessemer's invention was independent.

In the great days of American production, it was the fashion among steel magnates to talk down Kelly's achievement. There was a reason for this and it was not precisely an ethical one.

In 1871, William Kelly applied for a renewal of his patent. The rising steel men fought it, sent experts to the Patent Office to prevent the extension. Their private reason was that they were tired of paying royalties to Kelly. If the Patent Office refused to renew, the pneumatic process would become public property, royalty-free.

Yet when the testimony was given, one expert appeared who refused to lie. Alexander Holley, the man who had first brought the Bessemer machine patents to America, said, under oath:

"I consider Kelly's invention the first practical development of the pneumatic process. . . . Mr. Bessemer, by his superior mechanical improvements and capital, anticipated the results which might have followed from the development of the Kelly process."

In these words, Holley answered the whole question. If Bessemer had never existed, cheap American steel would still have come through the work of brilliant American engineers applied to Kelly's discovery. Indeed, much of the Bessemer machinery was soon discarded for American improvements. Even the earliest machinery was largely designed by American engineers. One of them has said publicly that "very few of the details of Mr. Bessemer's practice were embodied in the American work which was going on at that time."

Men said in 1871, and they have said since, that the Kelly patents delayed the development of Bessemer steel in America. These men ignored the value of that delay to the American technicians. In the years of the patent conflict, ingenious men, wrestling with the problems of mechanical invention which would be independent of the Bessemer patents, evolved new, valuable designs.

In the end, Bessemer made some ten million dollars. Kelly made less than half a million. Bessemer's fame spread over the civilized world. Kelly, today, walks among the ghosts. But the slow judgment of history must not be based on fortune and fame. Kelly's contribution was in preparing the minds of American iron masters for the new process. The demonstrations at Johnstown and Wyandotte proved that material for enduring rails could be made cheaply in America at a time when American railroad builders were blindly worshiping English iron and steel. It is unjust that the name of Kelly, whose nation has made far more pneumatic steel than any other, should be wholly forgotten.

6

BEHIND HENRY FORD

I

IN AUGUST, 1945, THE SECOND WORLD WAR WAS OVER. THREE months before, the Germans had given up; now the Japanese had followed. The tired Allied soldiers cleaned their guns and their rifles, put their equipment in order, and waited for the first step in a peace which, they hoped, was going to last forever.

All over the world stood machines, their missions over. Bombers—B-29's, Liberators, Marauders and Fortresses; fighters—Thunderbolts and Mustangs, P-38's and experimental jet jobs—rested, lined wing to wing in the dispersion areas of giant airfields on Owahu and Okinawa, at Orly and Bovingdon, San Diego and Casablanca. Long lines of tanks, thousands of half-tracks, staff cars, command cars, jeeps and peeps waited in the ordnance depots of Caserta, the motor pools of Capodachino and Manila.

The resting soldiers looked at these machines—some with affection and nostalgia, as cavalrymen in the old days looked at the rugged war-horses which had served them so well; some with relief that they would never again have to guide the iron monsters into the terror of flak or minefields. And the technical men, looking at the machines, said that they had won the war. The machines under the skilled hands of young men who had handled mechanical devices almost since they could walk, had beaten the German machines, the Italian machines and the Japanese machines.

"It wasn't that they were better," a fighter pilot would say.

"They *were* better," another would argue.

"I'm not so sure. The Messerschmitt was a honey of an aircraft. We never caught up with the Kraut jet jobs—"

"By that time it was all over."

"Yes, because we had more planes. More and more, always more. More tanks, more guns, bazookas, trucks. That was why we won the war."

Perhaps both the pilots were right. Perhaps certain of the planes were better, certain of the tanks less effective. But back of the planes and the tanks of the Allied nations there was something which could not be beaten. Back of all these things, back of the ships and the trains and landing craft that transported them, was a plan, a pattern.

In Detroit, in Willow Run, in Flint, in San Diego, in Kansas City, in Hartford and Bridgeport, in a hundred thousand towns, in shipyards along the coasts, workers stood along vast lines of assembly in August, 1945, and watched the work slow down. Here the last tank rolled off a conveyor, there the last steel plate—one of thousands precisely alike—was swung into place in the hull of a three-day liberty ship. For four years, day and night, with changing shifts and furnaces forever hot, the continuous process had never stopped along the lines of the endless belts. The whole country was a line with thousands of other lines running into it: trains on tracks, trucks on roads, transport planes on beams in the air; men, women, children, moving toward a main assembly, bringing skill and money and scrap iron and paper and energy and sacrifice and good will so that the movement over the lines of the pattern should never stop.

And what was the pattern? The answer to this is, perhaps, the greatest American story that was ever told.

2

A quarter century or so before the second World War—in 1915—a group of distinguished visitors went through a factory in Highland Park in the city of Detroit and believed that they saw something entirely new in the history of the world. Stretching so far that they could hardly see the end of it was a line of automobiles. Slowly, evenly, the line moved, slower than a man walks. As the visitors drew closer to the start of the line they saw, first, only a steel frame, then a frame with wheels, then, on the front of the frame, a radiator; far in the distance the cars grew taller. It looked like magic, as if these machines were growing by themselves as a tree grows. It was so sensational in all its even, steady, inexorable movement, its endless quantity, the quiet ease of it, that the visitors could scarcely credit what they saw—it must be a magician's gigantic trick turned with lights and mirrors.

But the magician at Highland Park, who was conducting the visitors, did not look like the kind of showman who pulls rabbits out of hats. He was a graying man in his early fifties, lean and hard in his build, with large hands and strong articulate fingers and a handsome Yankee face. It was a shrewd face—you could see the shrewdness in the little lines that gathered round his eyes when they narrowed, and there was a set to his jaw that told you he would be hard to bargain with; impossible to wheedle or fool.

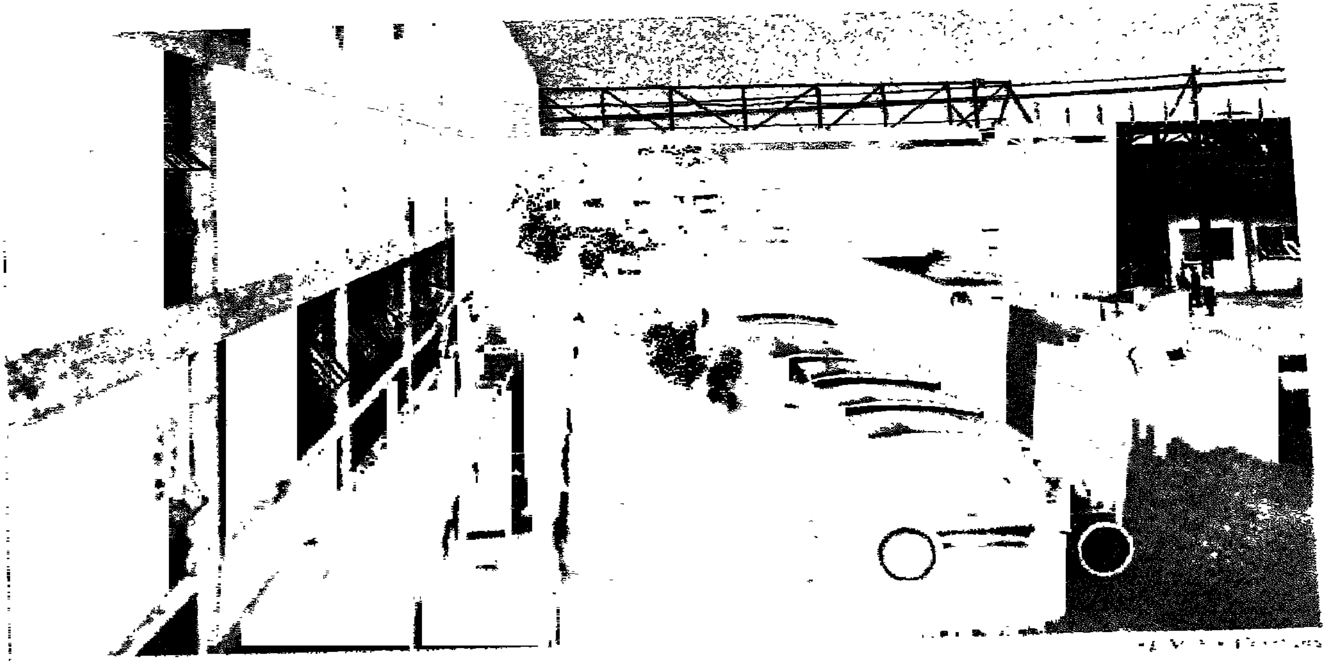
Nor did he talk magic. He talked figures, operations, timing; he talked material and machines.

"But it's entirely new," a young man kept saying. "The plan of it, the whole scheme, the notion . . ."

"Yes. It is new. The men used to walk miles from one part of the factory to another for their operations, and all the walking was waste motion. Now the workers remain stationary and the work moves to them, meeting them waist high."

He led them further along the line. They watched the frames or chassis on the endless conveyor, as each in succession came before a team of men. They saw one man insert a bolt, another put a nut on it, a third tighten the nut. Each man did a single, simple operation as the chassis on the conveyor passed him. The visitors went on to other teams of workers. Presently they saw other conveyors moving slowly overhead at right angles to the line of chassis. One carried wheels, complete with tires. A man would reach up, take a wheel from its hook, another would slip it on the axle, a third put screws in place, a fourth tighten them. The wheels would arrive on the crosswise conveyor at precisely the right moment for them to be attached.

As the unit containing the dashboard and steering wheel arrived on its conveyor and was fixed in place, the frame took on the look of a car. At the precise moment that the chassis



STAGES OF MODERN MASS-PRODUCTION

[illegible] Model T Ford [illegible] makes it easy to understand how [illegible] Henry Ford. The photograph [illegible]

Hauger and Dorf

came under it, the motor, arriving overhead, was lowered by chains into place, and a team of workers installed it. Finally, also dropping from above, was the body, glistening with its new black paint. As the conveyor moved slowly along, a tube was put in the gas tank of the finished car, another in its radiator; the crank was turned, the engine sputtered, the conveyor came to an end, the tires met downward-sloping runways. Then came the operation which left the visitors speechless. A man jumped into the driver's seat and drove the car under its own power off the end of the line.

The visitors then went along some of the crosswise conveyors. They saw the motor put together piece by piece as the men worked at lines of machines—machining pistons from the forgings, while another line of machine tools bored and finished cylinders, drilled them in a single operation for their valves; the cylinder line met the piston line at the right moment; pistons were slid in cylinders and the growing motor moved on.

This group of distinguished visitors saw these things in 1915 for the first time. They went out and told the world about it. They had, they said, watched history being made. They coined a new phrase about it—"mass production." Newspapers, magazines, books on economics began to use the words. Pictures were printed of the tremendous operation which was revolutionizing industry, and of its inventor. The world was told how, only a few years before, he had been an obscure man, though even then thousands of his ugly little black machines had invaded the cities and the countryside and were owned by thousands of "ordinary people"—farmers, mechanics and little businessmen who had never even owned a horse and buggy before.

This build-up was so effective that when, in the 1920's, the Encyclopaedia Britannica was preparing a supplement to its thirteenth edition, its editorial board chose Henry Ford to write the article "Mass Production." Whether he wrote it all himself —which seems unlikely as he was not a writer—or whether he was assisted by his company's high-powered publicity department, the article as it was printed is an interesting example of what sometimes happens to history when an individual achieves sudden fame.

"In origin," the article stated, "mass production is American and recent; its earliest notable appearance falls within the first decade of the 20th century. . . ."

It went on, then, to give practically no credit for the devising or the development of mass production to any person or group except the Ford Motor Company. Nor did it mention the fact that the *system of interchangeable parts* on which the whole pattern of mass production is based was put into practice one hundred and eleven years before the first Model T rolled into the streets of Detroit.

Mr. Ford, evidently, was naively unaware of the ghosts which, in the first decade of the twentieth century, haunted his plant in Highland Park—ghosts in knee breeches and lace cuffs, in tight pants and broad cravats and hard-boiled shirts and string ties.

3

Twenty-two years after thirteen American colonies had declared their independence of England, the young Republic was threatened with war. The threat came, this time from a new quarter—from an old friend, France. A revolution in France had been followed by the threat of a dictatorship. American newspapers were printing editorials about Napoleon Bonaparte and using very nearly the same words to describe him that they used a century and a half later to describe Adolf Hitler. And France was showing much the same disregard of the sovereign independence of other nations that Germany showed under Hitler. American ships, for instance, were being captured in the Caribbean by fast French frigates. So it was a time of alarm in all the western world, as it always is when a dictator begins to dream of conquest and empire. Fear swept the northern states—states like Massachusetts and Connecticut especially—because so many of their people were shipowners or captains or in some way engaged in foreign trade. The insignificant American army and navy of those days convinced these people that their hopeful young nation was wholly unprepared for emergencies and a great movement for preparedness began.

Soldiers were not hard to find. It was the question of firearms which was difficult. Rifles were rare. The small arms used by the army were largely smooth-bore, muzzle-loading flintlocks.

In 1798, a musket was made by a gunsmith at a forge and a workbench. First, by hand, he forged the barrel, then he carved out the stock and made the pieces of the lock, one after the other. Everything was trued and finished by eye. Each part had to be filed or hammered here and there until it fitted into its place. Finally the musket was complete; the gunsmith gave it a proud inspection, laid it on a shelf and started all over again on another. The result of this rule of eye and thumb was that each finished musket was slightly different from every other. The muskets, too, had certain characteristics peculiar to the "artists," as gunsmiths were called, who made them. A small arms expert could usually identify the work of a well-known smith even if his name were not stamped on it. On the battlefield, however, all these variations made it impossible to assemble one complete musket from the good parts of damaged ones.

Furthermore, this business of turning out works of art rather than products of manufacture took time. The most expert gunsmith must work several days at his bench to finish a single firearm. Thus, if it became necessary to arm ten thousand soldiers, say, within a year, hundreds of gunsmiths would have to start working at once.

The gunsmiths in this post-Revolutionary interval of peace were missing. Most of them, along with thousands of other enterprising artisans and mechanics, had gone West, lured by the fertile farm land of Ohio and western New York. It was a strange thing, this pull of the land on men who were skilled in the trades, because it was in the East that skill was most needed; in the East where factories and foundries were springing up everywhere. But Americans have always moved toward new empty spaces, restless to explore and settle them.

There was, however, one master mechanic—perhaps the most brilliant, imaginative and inventive American of his time—who stayed behind. Eli Whitney owned and managed a factory in New Haven. All day he worked with men, tools and machines making what he called an "engine" for the cleaning of cotton. He had invented this device a few years before and it had filled a desperate need in the South. Southerners dropped a syllable when they talked about it, calling Whitney's "engine" a "gin."

But Eli Whitney was playing a losing game. In the loose federation of the United States—a vast, lonesome country with few roads, primitive transport and slow communications—patent laws were impossible to enforce. Whitney's invention had been stolen; it was a simple machine, easy to make, and five years after he patented it hundreds of crude copies of it were making millions of dollars for the Georgia cotton planters and paying nothing to the inventor.

Aggravating this loss, workmen were constantly leaving his cotton gin shop for the West. He could find no skilled men to replace them. Night after night, he would stay in his shop, trying to figure how he could get his work done with *unskilled labor*. Somehow he must spread his own skill through the shop; somehow he must himself guide the hands and eyes of untrained men.

Step by step, he thought out the answer until a whole new pattern had spread before him.

He began with a simple argument. An untrained man could draw straight lines or perfect circles freehand. Each line and each circle would be slightly different from every other. But by driving two nails in a board and stretching a string between them, he would have a straight-line guide for his crayon. From this he could make a piece of wood or metal which would have a straight edge. Men had learned this trick thousands of years ago. With this edge or ruler in his hand, a wholly unskilled person could make thousands of straight lines, all exactly alike. So, too, with a string tied to a nail and a pencil tied to the other end, the pencil could make a circle. Out of this evolved the compass, a tool made of two prongs clamped together; if one prong were held on a point, the other would describe a circle, and with this tool thousands of circles, all alike, could be drawn. These tools crystallized one man's thought and reasoning—with them his thought and reasoning could be reproduced an infinite number of times by other unthinking, unreasoning men.

Why, thought Eli Whitney, not multiply these tricks indefinitely? Suppose you had to drill several holes in a piece of work, holes of different diameters, say, a certain distance apart. Suppose a hundred pieces of work had to be drilled just alike. In the shops of the day this was done by laboriously measuring the distances on each separate piece with a rule. Why not do it once on a piece of metal, drilling your holes in that and using it for a pattern, putting it over each new piece of work and drilling through the holes? Then each finished piece would have all its holes in precisely the same relationship to one another.

From these simple beginnings, evolved the system of what are called "jigs" and "fixtures." Clamps and other devices to hold pieces of wood or metal in place as tools worked on them —a gadget on a lathe, for instance, which would automatically remove a tool from a wheel that was being turned when the exact required diameter was reached—all these things replaced the human skill and at the same time produced an accuracy which skill of eye and hand could never achieve. With machines of this sort Whitney replaced his trained men. With such devices, twelve-year-old boys could work with the proficiency that it had taken experts half a lifetime to learn.

Whitney used these jigs and fixtures on his cotton gins. But even with the quickened work, the business did not pay. The gins had to be shipped too far and were often lost or damaged on the way. Cotton harvests waited for no man. It is hardly just to blame the planters, surrounded by potential riches, for using Whitney's idea and building their own machines.

Whitney sought, therefore, a new outlet for his energy and inventive power. If, he thought, he could use his new tools and machinery for something else—some smaller device for which there would be a large, immediate demand nearer than Georgia—he would abandon the gins and concentrate all his skill and equipment upon it.

It was at this point that he heard the rumor of war with France. He had been too busy to keep up with home politics, let alone international affairs. Suddenly he realized that with the threat of war there would be an instant need for thousands of firearms. With his new machine tools, perfected muskets which trained gunsmiths had made one at a time, could be turned out by the thousand with only a small staff of unskilled workers. One set of machines boring and finishing barrels, another shaping triggers, another sears, another lock plates! The machines all working at once and the various parts sorted in separate piles, each part precisely like its fellow and each fitting in its place when the time came to assemble them!

Obsessed by this concept, Whitney wrote to his friend, Oliver Wolcott, in the Cabinet of the Federal Government in Philadelphia.

"I should like," he said, simply, "to undertake to manufacture ten or fifteen thousand stand of arms."

It would be surprising, unless we knew all the circumstances, that the promise of such a feat from a New Haven mechanic could be taken seriously by a realistic Cabinet officer. But Whitney was not unknown in the councils of state. In his tough, stubborn fight for his patent rights on the cotton gin, he had made many friends. Vice-President Thomas Jefferson, an inventor himself, had admired the simple, efficient cotton machine. And there were men in the government, as well as in Congress, who had known this young man at Yale.

With this start, the subject was argued back and forth by experts in firearms. Even with Jefferson's assurances, some of them could not credit Whitney's offer. But it is history that, in the early summer of 1798, Whitney was given a contract by the Federal Government. It called for ten thousand muskets in two years—four thousand to be delivered in the first fourteen months.

What this stubborn, fighting young man went through that winter, we can only guess, for he kept no record. We know that Connecticut experienced one of the worst winters in its known history. From the few letters that Whitney wrote, we know that the water in the millraces froze so solid that heavy machinery stood idle for months; that he had to wait through long, bitter weeks for the iron for his machines to be delivered by sledges drawn over the snow. During all that time, he must keep himself and his men busy, interested, with faith strong and morale high. But Whitney had the sort of mind which, when thwarted in one direction can turn instantly—almost automatically—in another. When the mill irons did not come, he turned to planning, plotting, inventing. He laid out floor plans for his factory. On paper he organized the division of labor. He never stopped inventing new machines; in his mind's eye he looked for hours at his sketches. He could see the wheels turning, milling wheels grinding into wood or metal, drills and borers biting out their holes or shaving the inside of barrels. Eli Whitney was not an occasional inventor; he was a constant inventor—he invented in every waking moment of his life.

The government officials in Philadelphia, however, knew nothing of all this. They knew, simply, that when midsummer arrived and the first four thousand muskets were due, none were delivered. Whitney's backers grew anxious; friends who had lent him money wondered if they had been sponsoring a dream.

In the fall, a Federal arms inspector came to the factory. He was skeptical even before he talked with Whitney. On his way through New Haven, he heard rumors which alarmed him.

"Whitney is not making muskets in his mill."

"You don't make firearms without benches, without artists."

"What has this tremendous overshot water wheel he has built got to do with muskets? What are all these engines in his shop? Why has he bought these mill irons, these rolled iron rods? The chances are he is building big, new cotton engines and making the government pay for it!"

At the factory, the inspector found that these rumors were not idle gossip. He saw nothing familiar. The lathes, millers, drills cluttering the shops seemed to him to have no connection whatever with firearms.

"Where," he said to Whitney, "are the muskets?"

Whitney's eyes focused slowly on this stranger as his thought moved from the problems of forging, rolling, boring, grinding and polishing to the vision of a finished musket.

"Oh," he said, ". . . muskets."

"That," said the inspector, "is what I am here for."

Whitney led him through the shops, showing him the new machine tools. But there were only five hundred finished muskets.

"Your contract," the inspector said, "calls for four thousand. You are already late in the delivery."

"I have had trouble with labor and materials," said Whitney, in words which have had many an echo in modern times. "But," he added, "I have got the machinery finished. *I have the machinery for ten thousand muskets.*"

Those words told a new story in the history of the world. Today a manufacturer in the same circumstances would say:

"These jobs you see are 'experimental' or 'demonstration' or 'model' cars. But my plant is *tooled* for a production of two million."

But in Whitney's day, such words had never been spoken and the inspector had not the remotest idea what they meant. To him, if you made five hundred guns in two years you would make a thousand in four years and it would take forty years, naturally, to make ten thousand.

When the report reached the government, even Oliver Wolcott was worried. Things moved slowly in those days, however, and the government was busy with other concerns. For one thing, it was moving into a wild swamp beside the Potomac where, one day, the city of Washington would grow.

So it was not until the fall of 1800 that the government actually threatened to revoke Whitney's contract. Wolcott wrote then to his friend, advising him to make the long journey to Washington to demonstrate his system before the experts, so that they could see with their own eyes what he was attempting to do.

By the time Whitney arrived, late in the winter, in Washington, Wolcott had aroused considerable curiosity in his experiment—so much so that even the President, John Adams, wanted to see the demonstration.

Whitney brought with him a box containing the mixed parts of ten muskets. He opened the box before the President, Jefferson, Wolcott, various Cabinet members and a gathering of small arms experts. He arranged the parts in piles—a pile of barrels, one of triggers, one of sears, one of flintlock "batteries" or "frizzens" and so on, until all the parts were on the table. Then he asked someone to pick *at random* one part from each pile until pieces enough to make one musket were gathered together. Then he let a member of his audience assemble the musket.

It was a startling demonstration and seemed hardly credible. Some of the spectators refused to be convinced. There was always the possibility of a trick—that Whitney by years of work had made ten muskets with parts so precisely finished that they were interchangeable. It was at this point that Thomas Jefferson spoke.

He had, he said, seen something like it fifteen years before in France. He had realized its importance and had tried to bring Leblanc, the inventor, to America, but the French Revolution had intervened and the man had disappeared. Whitney, he said, had carried the process beyond the point Leblanc had reached and had actually made complete finished muskets by it, whereas Leblanc had produced only the lock. It was evident that Whitney's machinery was more practical.

The word of the Vice-President, who stood at that moment on the threshold of the presidency, convinced so many of the group that the time of Whitney's contract was extended.

Later, after the muskets had been tried and proved by the army, the government helped him with money and patience and new contracts. From then until his death he was never without a government contract, and in the next twenty-five years he improved his machines and enlarged his factory until it was famous throughout the country.

4

More than a century passed between Whitney's first designs and the tooling of the Model T plant in Highland Park. As we look back down that long road of progress we see the ghosts of many brilliant, persistent inventors, mechanics, engineers standing upon it. There was Simeon North who thought of the interchangeable plan independently, a few years after Whitney, and used it for pistols. There was Samuel Colt who learned it from Whitney's son and improved it for his revolver, the fame of which spread quickly over the civilized world. In 1851, at the Crystal Palace Exhibition in London, a demonstration by the Vermont manufacturers, Robbins and Lawrence, of the assembly of rifle parts made on the Whitney plan so amazed the Englishmen who saw it that the British Government sent a commission to America to study what was called "The American System." As a result, the Enfield factory was established in

England and thus, for the first time, more than half a century after its invention, interchangeable parts manufacture crossed the Atlantic. It is hardly surprising, therefore, that America gained a lead in the large-scale production of machines that was never overcome.

Gradually, inventions multiplied, the process moved away from firearms into other, more complex kinds of machine manufacture. Cyrus H. McCormick, whose invention, the reaper—a machine for cutting grain in the field—did more for the conquest of the American continent than any other single device, had a development of the Whitney system in full operation in his Chicago factory in 1850. The first version of the moving conveyor line appeared in this factory, and was described by an astonished reporter in flowery language for his newspaper.

> "An angry whirr, a dronish hum, a prolonged whistle, a shrill buzz and a panting breath—such is the music of the place. You enter—little wheels of steel attached to horizontal, upright and oblique shafts, are on every hand. They seem motionless. Rude pieces of wood without form or comeliness are hourly approaching them upon little railways, as if drawn thither by some mysterious attraction. They touch them and *presto,* grooved, scalloped, rounded, on they go, with a little help from an attendant, who seems to have an easy time of it, and transferred to another railway, when down comes a guillotine-like contrivance—they are mortised, bored, and whirled away, where the tireless planes without hands, like a boatswain, whistle the rough plank into polish, and it is turned out smoothed, shaped, and fitted for its place in the Reaper or the Harvester. The saw and the cylinder are the genii of the establishment. They work its wonders, and accomplish its drudgery."

At about the same time, Isaac Merritt Singer put the same system into a factory for the more exacting manufacture of the parts of sewing machines. Meanwhile, in the making of clocks, it had been used by the Yankee, Eli Terry, who, before 1820, had produced five thousand cheap, accurate clocks a year, an achievement which was talked of in Europe as an unexplainable feat of magic.

In time this large-scale production was recognized as an American tradition woven closely into the whole fabric of our history and of our social democracy. It arose from a cause which was wholly, uniquely American. That cause was, first, shortage of labor. The empty country to the West was drawing men and women to it as a vacuum draws air. Yet when these pioneers established the new settlements, they found themselves desperately in need of things they could not make in places where the land took all their time and attention. These things—thousands of them—had to be supplied. The East must supply them. So machinery was invented.

But there was something more in America which made mass production a natural evolution. The Declaration of Independence had been clear on the point that all men had been created equal. People accustomed to life in a wilderness did not have to be told that. In order to live, everyone had to do his share of the work, none could have special privilege. But as civilization brought the growth of cities, inequalities developed. Certain men gained control of wealth, and through money could make others work for them. Round the centers of wealth, there grew a fringe of poverty and equality disappeared.

Yet the belief in it persisted. In his heart every American honestly believed himself "as good as the next man," and he was determined to overcome anything that stood in the way of his proving it. The whole social consciousness was the reverse of that in Europe. There every manual worker expected to go through life as a manual worker and hoped for no better fate for his children and his children's children. But in America, the lowliest sweeper or ditchdigger told his boy that some day he might be President. Whatever poverty and misery closed him in at the moment, there was always that "some day" in his mind.

So when good things like the sewing machine or the bicycle arrived, the poorest American believed that some day he too would own one. The pressure of this thought was tremendous. And the pattern which Whitney and North and Colt and Terry had designed made it possible to realize this dream. Indeed, that system was so geared that it was unprofitable for it to produce anything but cheap goods. The scale on which factories operated, once they adopted it, made it essential that there be a demand ten or a thousand times as great as ever before for the goods they turned out—otherwise part of the fast, new, productive machinery would have to stand idle with consequent loss to the manufacturers.

So the whole scheme fitted together as if it had been planned beforehand. Actually, as we look back at it, we see that each step forced the next step. The sense of liberty and equality given by the wilderness forced the Declaration of Independence; the desire for more freedom and independence forced the westward movement; the westward movement drew the artisans away from the factories and forced manufacturers to replace them with machines; the machines forced the wholesale production of goods and this in turn forced large markets for these goods among people who had kept their conviction that no man deserved luxuries more than any other; and this combination of demand and supply turned luxuries into necessities and made them available to everyone. It was as automatic and uninterrupted as an assembly line.

There were, of course, other factors. Businessmen made such social inventions as installment buying. When Singer, for instance, offered to place a sewing machine in a home for only a small down payment and let the machine earn its cost; when McCormick gave a farmer a harvester for a trifle and let the farmer pay the rest out of the next harvest—such things were almost unheard of in Europe. These things, plus the important fact that all through the nineteenth century in America there was always new land, always new opportunity, built our social democracy and a high standard of living. When the frontiers closed, when the empty land was filled, there were difficulties, but by that time the nation had solidified, had grown united, had conquered its vast savage continent and was sufficiently vigorous and ingenious to find new frontiers inside itself. It was then—in the dawn of a new and a very different century—that Henry Ford arrived.

5

Ford's biographers explain that as the boy grew up on the Greenfield Farm near Detroit, he was obsessed with visions of bigness. "I wanted to make something in quantity." In that age—the 1870's and 1880's—there was nothing peculiar about these thoughts. Boys were having them all over the United

States. Everything that happened round them was big: the transcontinental railroads, the bonanzas in the Nevada gold and silver mines, the telegraph which reached out under the Atlantic to Europe, factories which made a hundred and fifty thousand clocks, more than fifty million yards of cotton cloth, twenty-five million pairs of shoes a year. These figures look insignificant today, but they were enormous to the boys of Henry Ford's time and they had come to this point in a nation less than a hundred years old; a country which fifty years before had been largely wilderness and virgin forest. Only a few miles from the Ford farm, the city of Detroit was doubling its population every ten years, and a large part of this increase came because boys left their farms to take part in the industries that grew like mushrooms in the city.

Opportunity was everywhere: the chance to do big things on the scale of the most fantastic dream. Nothing was incredible, nothing impossible; men were growing rich almost overnight in the cities, making the millions of things for which there seemed a limitless demand. It was hardly surprising that a boy of Henry's spirit, energy, passion for machines and talent for making and running them should have been lured from the dull routine of cows and corn. Nor is it odd that having seen the work machines could do, the vision came bright in his mind of more and greater work—the vision, in short, of mass production toward which the whole of industrial America was moving so fast.

So there was nothing new or original or startling in the conception of turning out a million or more useful machines and making them cheap enough to be owned by people with small incomes. Harvesting machinery and sewing machines and bicycles had been in the homes of lowly folk for years. The only novelty came when this vision was applied to automobiles.

The automobile was invented in Europe. Carl Benz and Gottlieb Daimler in Germany were responsible for most of its essentials; De Dion and Panhard in France supplied the others. In Europe it belonged to the rich. When it arrived in America, the idea that it was a millionaire's toy came with it. Foreign cars blossomed out in Newport and Saratoga, the playgrounds of the rich. When American mechanics in the middle 1890's began making "horseless buggies," it was not with the idea of using them themselves to get about or to help the farmers, but to sell these vehicles to moneyed people with plenty of time for sport—to sell them for "daredevil" racing or vacation touring. So, after the first crude experimental jobs were built and proved practical, the emphasis was on making them fancy and luxurious—not on making them cheap and available to the masses.

It was Ransom E. Olds, not Henry Ford, who first broke this prejudice. Ford was still making racing cars when Olds designed what he called a "runabout," taking its name from a light horse carriage popular at the time. The Oldsmobile looked like a horse runabout without the horse, but he took some of the horseless curse off it by curving the dashboard. The important thing about the Oldsmobile was its simplicity, its lightness and its cheapness. It weighed seven hundred pounds, cost $650 and was considerably easier to drive than a horse. It had tremendous appeal, especially to women, and before Olds' company abandoned it they were making five thousand cars a year which required a more complex mass production factory than the world had yet seen. It was abandoned in 1906 for two reasons: first, because the big luxury-car market was still so profitable; second, because the little Olds would not do a real people's job. It was, actually, a mechanized light carriage. The horse runabout had been a fancy little affair, used mainly by privileged people to drive to their country clubs, and replacing the horse with an engine did not change it enough to make it appeal to hard-working, plain people.

All the same, it was the Olds which first paved the way for the universal acceptance of the motorcar as a necessity. It took so little learning to drive. It was easy to fix. And when some twenty thousands of it were in operation on the country's roads, the common sight of it accustomed people's minds to a horseless age. But more than this, it paved the way *literally*. Its owners began to insist on the improvement of the terrific dirt roads which were far worse in America in the early 1900's than in any part of western Europe.

It was at this point—just as the Oldsmobile went out of production in 1906—that Henry Ford got his great idea. He would make a car that would be first, last and all the time, useful—and nothing else. That was the idea that brought the "Tin Lizzie" into existence. She never varied. There were no new models. For fifteen years, the same high, snub-nosed, cloth-topped, black embodiment of ugliness poured out of the factory in Highland Park. "You can have it painted any color," said Ford to his customers, "so long as it is black." Beauty, in Henry's view, was something plain people did not want and should not have. His Lizzie would never be a painted woman.

In the newspapers and magazines, in shows, in the movies, the wits kidded the Ford; for years the country rocked with laughter at the Ford jokes. There was a new one every minute. But there was a new Ford every minute too, and people bought them. They laughed while they bought, while they drove. They helped one another out of ditches, out of the mud, swapped parts, mended breaks with hairpins, paper clips, pipe-cleaners and bent nails. A farmer would shout "Git a horse" when a Ford bogged down near his farm and he would bring a team to pull it out—but a month or a year later he would own a Ford himself.

It was the Model T which began to change the social geography of the United States. Between 1910 and 1925, the scheme on which people had built their homes and communities underwent a tremendous alteration. That plan had been laid out, for the West at least, largely by the railroads. Now little, forgotten hamlets and villages, far from the railroad tracks, grew into prosperous towns. It was no longer necessary to live near the railroad line to be part of the commercial world. Great quantities of land were discovered by the driving population, and farms grew up in places that had been thought inaccessible and unprofitable. At the same time, branch spurs of railroads which had been kept up at much expense to serve small communities were abandoned. Now the communities could live and thrive without them. Outlying farmers could get their goods to market. Factory workers could live farther away from their work, out of the crowded cities, yet still get to their jobs on time. A whole new world came into being.

These changes and the other later ones—the new, profitable activities of tourist cabins and "homes," the roadhouses, the roadside stands by which a farmer could sell his fruit and vegetables on his front doorstep—these things cannot all be credited to Ford. But it was he who began them; it was he who first made the population of the country, as a whole, aware of the possibilities of the future. And the great trucks of today, the big powerful passenger cars and the trailers are moving over roads paved by the Model T.

But this story is about mass production. We have seen that Ford had nothing to do with its origins. We have seen how completely large-scale production based on interchangeable parts had become an American tradition long before there were any factories in Highland Park. This tradition had created demand, markets, a democratization of luxuries which existed nowhere else in the world. What then did Ford contribute to mass production?

Except, perhaps, for Eli Whitney who invented its basis, he contributed more than anyone else. He did this without being an inventor in any strict sense of the word. He took all the inventions he could find which implemented the production of cars and engines—and this included thousands of devices—and co-ordinated them. He took, for instance, the electric motor; applied small individual motors to individual machines in his factory. This made it easy to put these machines anywhere he liked, instead of lining them up so they could be belted to a shaft run by a steam engine. Thus, instead of having all the lathes in a line along one shaft, all the planers along another, all the millers along another and all the drills along another so that the work would have to be taken long distances to have each operation done on it, he could group a series of different kinds of machines, each with its own motor, so that a *successive* lot of operations could be performed on a piece of work in a small space. He was able to put, for instance, the electric furnace right in line with other machines so that operations of hardening, say, could be done at precisely the right moment on a cylinder without leaving the motor assembly line. This kind of combination, along with the use of conveyors everywhere, saved the workmen miles of steps, hours of time and did away with the dangerous, noisy, ugly, nerve-wracking system of belts and shafts which, in the factories of the country, had taken their toll of thousands of deaths and injuries a year.

But Ford went far beyond Highland Park and beyond the great River Rouge plant to which he later moved. His system of continuous movement extended all over the world. He spread it over the territory needed for his raw material; iron mines, lumber camps, textile mills, rubber plantations, coal mines. The movement of ore-loaded cars from the iron mines, of coal cars from the coal deposits, of ships carrying raw rubber, of trains full of cloth and boards and paint and brass and copper wire—all the hundreds of things that found their way into the little cars—were timed and scheduled in the Ford offices so that everything would arrive at the main assembly line at precisely the right moment when a new chassis moved under the hands of a team of workers.

Ford, at River Rouge—after Lizzie had become modern and streamlined—used to boast that there wasn't a warehouse in the place.

"But where," the amazed visitor would ask, "do you keep your supplies—your rubber, the yards of upholstery, the fuel for your generators . . ."

"It is all on cars or ships, moving, forever moving," Ford or his right-hand man Sorenson explained. "It never stands still. It keeps pouring in. We need no warehouses because everything is used the instant it arrives."

Because of Ford, too, mass production on his basis of continuous, assembly-line operation became necessary in hundreds of other industries. Because so much material was needed so fast, new automatic strip mills, for example, had to be invented to produce sheet steel for bodies. New plans had to be devised for the production of paint, as well as new kinds of paint which would be quick-drying without loss of quality or endurance capacity. New laboratories had to be set up for the making of metal alloys—combinations of iron, carbon, molybdenum, vanadium and chromium which would be subject to quick, easy working on the machines of the assembly line.

And along with the growth of Ford came the tremendous growth of his rivals and competitors, all of whom had to adopt his methods. In this way our whole economy was affected until, when the second World War came, the nation was ready for the kind of production which seemed incredible not only to the outside world but even to those Americans who had not followed, step by step, hurdle by hurdle, the colossal movement of the process.

6

If Henry Ford or any single technical or business genius had been able to create the system which made us equal to the great emergency when it came, it would have been incredible indeed. But when we know that, like American democracy, it evolved slowly over a century of time, that its steps were answers to desperate necessity, that it was all an integral part of conquering a vast savage wilderness so quickly and so completely that the nation never split apart or lost its unity and, finally, when we realize that the whole people co-operated in this evolution, it is no longer a miracle.

There is a word that has been on everyone's lips in late years; a word which explains the beautiful flexibility of mass production—"The American System" as it was once called—in its application to war. The word is "Conversion." The idea of interchangeable parts carries with it the great corollary of convertibility. Begun for war, it was converted to the uses of peace and it grew to its full stature. By the time of the first World War it had become so flexible that it could be converted to war use with great speed. In World War II, plants for making cars could be converted into airplane plants, and even factories which made women's compacts or electric light sockets could be converted in a few weeks or so to the production of ammunition cases. In the war of 1941, almost every factory in the United States which made machines or gadgets of any sort, from bedsprings to the most complicated engines, from tin cans to car bodies, was using some of its capacity in the production of parts for weapons. And when the war was over, such a plant as Willow Run, where aircraft first went into true mass production, was ready in less than a year for Kaiser-Frazer passenger cars.

There are pitfalls in the mass production system. When it breaks down the losses are on a mass scale. Strikes have a far worse effect upon it than they have on a less integrated system.

When the timing of the production of one industry is upset, the breakdown is quickly felt in almost every other industry in the nation. And mass production is always geared to mass consumption; when the demand for goods slows down—as it does for example in a depression—losses are on an enormous scale. Mass production, with its every tool dependent on every other tool, its every worker waiting upon the act of the worker next to him, must run smoothly and at full capacity, otherwise there is no profit in it. If a plant is geared to produce, say, four thousand cars a day and three thousand of the people who daily want to buy a car suddenly find themselves too poor, then the slowing down of the line to a thousand-car daily production forces the manufacturer to lose money on every car he makes.

So there is work here for that other genius, the social inventor, to do. The maintenance of peace, the distribution of our infinite capacity to produce so that every human being can have his proper share of the production—these are his job. He has much work ahead of him.

7

BEHIND THE SCREEN

I

THE ROAD TO PRESENT-DAY HOLLYWOOD IS LONG AND WINDING, and traverses Europe as well as America. On it are many ghosts; forgotten men who gave much of their lives and energies to the magic which has become our commonplace. They are forgotten partly because their contributions came in a time of many inventions, when patent law had become a cumbersome business. Other men, mass-inventors, so to speak, like Thomas Edison, took their plans into an "invention factory," and they came out with the mass-inventor's name stamped on them. Such things happened too fast for the slow machinery of the law to catch up with them, so the credit got lost and many a brilliant originator became a ghost. Americans were coming in those days to like familiar labels and if the magic label of Edison, "the Wizard" appeared on anything, no one bothered to find out whether Edison had really invented it or had bought or wangled it from someone else. But some of the forgotten men had great adventures on the road to Hollywood—exalted hope, long, tireless searching, dark despair. Occasionally the adventures were as romantic as any of the modern movies themselves.

2

On a September day in 1890, a Frenchman, who had taken out his papers for American citizenship, got on a train at Dijon in France, to travel to a channel port. He was headed, eventually, for New York where his wife and family were living and where, he believed, a brilliant career lay ahead of him. On the way, he would stop off in England, pick up some important baggage and go on across the Atlantic.

Louis Aimé Augustin Le Prince was, at the moment, on vacation after years of intense effort. He had worked stubbornly, in the face of repeated failure and difficulty, in New York and in Leeds, England. Now he had got to the point where he could leave Europe for good, settle down in his adopted country, complete his experiments and get American backing for the development of his inventions. He had gone on a hurried trip to France to say good-bye to his brother there.

His brother went with him to the station. The train left, Augustin Le Prince waved from the window. And from that moment, he was never seen again. He simply disappeared, leaving no trace. Frenchmen said he was murdered by a jealous rival. The police suspected that there had been a common robbery, but there was no clue, no evidence. At the time, his work and his achievement were known only to a few of his intimate friends. But we know now that, at the moment of his disappearance, he had made the full, basic invention of the motion picture camera and projector.

In New York, through the fall, his wife and children waited for him, ignorant that any harm had come to him. It was not usual in those days for people to telegraph and cable one another about arrivals or departures. Mrs. Le Prince knew that her husband had gone on a short vacation to France, that he would then go for a week or so to England before coming home. For a time, when the incoming steamers did not bring him, she assumed that some unexpected thing had delayed him. There was his vital baggage, for instance, in Leeds; cameras, lenses, much equipment which must be carefully packed.

But as the weeks passed, Mrs. Le Prince and her son and daughter, living in the old Jumel mansion, surrounded by Augustin's things—photographs he had taken, cameras he had used in his New York work—began to worry. The little family met every steamer. Finally Mrs. Le Prince told her husband's friends of her anxiety and they got in touch with Albert Le Prince in Dijon. He had heard nothing. He notified the police and an investigation began which lasted for years without result. Methods of criminal investigation in 1890 were not comparable with those of today and, furthermore, the murderer—if there was a murderer—had had plenty of time to cover his trail.

If Le Prince had lived, if he had come to New York as he had planned, the history of motion pictures might have been different. Americans might have seen screen projections years before they saw the slot machine peep show called by Edison the kinetoscope. The whole progress of motion pictures might have been advanced. Some of the details Le Prince worked out, such as the 2⅛ x 2⅛ frames which were replaced by the 1 x ¾ standard of Edison, would have greatly improved the pictures.

When hope of finding Le Prince had been given up, his widow, his son Adolphe and the little group of his loyal friends got together what they could find of his equipment and plans to prove priority of his claims. They found a sixteen-lens camera which he had patented in America and a single-lens camera patented in England. They found a projector and rolls of film; they found strips of developed film with sharp, clear pictures proving that his camera was not a mere idea but that it worked. Most important of all, they found that his British patent called for the movement of the film by sprockets fitting into perforations on the film edges. These perforations were later a great source of contention when the Edison patents multiplied.

It was natural for these devoted people to try to keep their friend from being forgotten, from being one of the procession of ghosts on the road to this great invention. But their efforts were fruitless. The public seldom gives credit to the inventor who thinks, plans, experiments in his lonely laboratory unless he carries his idea through to full usefulness—to production and commerce. Le Prince, like many another mechanical genius, was thwarted on the carry-through by backwardness in other inventive fields. The great obstacle in his way was the lack of celluloid film. On the very eve of his death, this flexible ribbon film came out of the laboratory of the Eastman Kodak Company and went on the market. Le Prince's film was a close approach to this, but it was not close enough. In this same year —1889—a piece of this Eastman film found its way into the great laboratory of Thomas Edison and started a train of thought which, as we shall see, came to dominate the entire motion picture industry—though for years after La Prince's death it never approached his basic idea of throwing pictures on a screen. But there were other ghosts that it would be well to meet before we come to that solid, flesh-and-blood character who finally brought dreams to the production line in America—for it is the combined thinking of these forgotten men that, in the end, made it possible.

3

The principle behind all movies is a failing in the human eye, plus a power in the human imagination. The eye weakness is called "persistence of vision." If something you are looking at is suddenly blacked out, you continue, for a fraction of time, to see it. So, if the light goes on almost instantly again, the image of the thing you saw before carries on into the image you see when the light comes back.

The old, simple experiment to show persistence of vision is the trick of the boy at the bonfire who whirls the glowing stick at arm's length. What you see, when this is done, is not a point of light at successive points in a circle, but a whole solid circle of light. This means that, if the boy starts his stick at the bottom, by the time it has whirled to the top, the bottom glow is still visible. Thus persistence of vision is easily and quickly proved.

But we have not yet explained the movies. On the contrary, we have explained something which is the precise opposite of the movies. For here, the moving light has given the illusion of a motionless circle, whereas in the movies, motionless pictures give the illusion of movement. So there is a catch here; something more than persistence of vision is necessary.

The catch was seen by a professor of psychology, Hugo Münsterberg. Psychologists are rarely content to accept explanations which involve the eye—or any other organ of the body—alone. The invisible, intangible mind behind the physical organ must come into it. The mind is a collection, a vast storage of all experience. The illusion of motion, Münsterberg said, "cannot be reduced to a simple seeing of different positions." Thus, when you see a picture of a man whose arm is level with his shoulder and then quickly see another picture in which his arm is higher than his head, and the quick succession of these pictures makes you believe you see the arm actually move upward, the fact that the first image persists until the second appears does not explain your sense of motion. There are many positions of the arm between the two pictures, which you have never seen at all. Unless these positions were somehow supplied to your mind, mere persistence of vision would cause a click or a blur as the pictures followed each other. What supplies them? Münsterberg's answer was that it could be nothing but the imagination—that mysterious, creative human faculty that makes it possible for the mind to see something that has been invisible to the eye.

Here the eye sees two pictures, say of a man, one with his arm raised to shoulder height, the second with the arm slightly higher. But the eye has not seen the arm occupying any of the intermediate positions; it has not seen the arm move. But when the eye sees the arm in the level position and then, quickly, before that image fades, sees it again higher, and when it telegraphs the messages about these things to the mind, the mind is so sure that the arm *must* have been moved that it *creates* the motion out of pure fancy.

These tricks of the eye and the mind have fascinated those observing people who reflect upon and analyze what they see, since before the Christian era. The phrase "persistence of vision" was invented by Titus Lucretius Carus, a Roman, in 65 B.C. "When the first image passes off," said Lucretius, "and a second is afterward produced in another position, the former then seems to have changed its gesture." The scientific world, however, did not seriously investigate the illusion until the nineteenth century. Then, in the 1820's, Peter Mark Roget—more famous for his *Thesaurus* of English synonyms—discovered the important principle of the slit, which started a whole army of experimenters.

Roget slept in a room with Venetian blinds made of vertical slats. Waking early one morning, he saw through the blind a moving cart; the spokes of the wheel were so distorted that he believed he must be still asleep, having a fantastic nightmare. He opened the blind, then closed it again, and finally became convinced that the blind caused an optical illusion. The image he saw through one slit carried over to the image he saw in the next. The illusion he had was one which was going to plague movie people a century later when, every time they shot and projected a moving spoked wheel, the wheel on the screen seemed to be standing still or moving backward. But the important result of his observation was that, when he told about it in a paper which was read before a society in England, many curious people began to look at things through slits. And in the slit was the first basic motion picture necessity. The slit gave a glimpse which quickly vanished, and the fundamental requisite to the motion picture illusion is the quick vanishing of glimpses, for in the blackout between the glimpses take place those twin phenomena, persistence of vision and the imaginative creation of motion.

The first half of the nineteenth century was a strange and interesting time, for science was replacing magic in the public mind. We have seen how Benjamin Franklin demonstrated that lightning, which until his time had been considered a manifestation of the wrath of God was, actually, the action of a calculable and extremely useful force. In Roget's time, Michael Faraday was proving its usefulness. Presently, Joseph Henry would use magnetism to send messages over long distances and Kelly and Bessemer would reduce the magic of steel making tc a set of chemical formulas.

The public took these things in a rather naive and childlike way. They thronged to exhibitions of the new "science," like children going to a magician's show in a gay and excited mood, ready to gasp "Oh" and "Ah" as each new marvel was displayed. They also bought quantities of scientific toys. So when distinguished scientists like John Herschel, Charles Babbage and others made various devices of cardboard to prove to themselves the facts behind optical illusions, these things became profitable. One device was a cardboard disk made to spin over and over on its diameter. On one side was a picture of a bird; on the other a picture of a cage. When the disk was spun, the observer saw first one side and then the other. The movement was so rapid the bird seemed to be in the cage. The toy was a best seller among a large portion of the adult English population. Because the public liked scientific names the toy was called the "Thaumatrope." It was not in any sense a motion picture, but it did prove beyond any doubt that the image of a glimpse did persist after the glimpse had vanished, thus giving further validity to the slit theory.

With the added profit motive, experiment spread rapidly. In Belgium and in Austria, at almost precisely the same moment, there arose the first real technical fathers of the motion picture. These were Joseph Antoine Ferdinand Plateau and Simon Ritter von Stampfer. Their inventions were virtually identical. Two cylinders, one inside the other, turned on a shaft. On the outer surface of the inner cylinder were drawn pictures of successive phases of some very simple motion such as those displayed by a man walking. Through the outer cylinder, slits were cut. When the cylinders revolved the pictures were seen through the slits in quick succession and the observer saw a moving picture.

The inventions of Plateau and Stampfer, called, respectively, the "Phenakistoscope" and "Stroboscope," were still a long way from what a more sophisticated modern public is content to call the "movie." But they were working in 1832. Photography had not been invented. The machines of Stampfer and Plateau merely showed animated cartoons, and showed them to only one person at a time.

4

The step from individual toys to collective entertainment took twenty years. In 1853 Franz von Uchatius, an Austrian army officer, produced a device which hitched the toy to a "magic lantern" invented in 1646 by a Jesuit priest, Athanasius

Kircher. The combination threw animated cartoons on a wall. Uchatius brought another basic device into motion picture history. This was the shutter which, moving before the projecting lens, blacked out each successive picture after it had been flashed on a screen by light passing through a glass revolving disk on which the pictures were painted. A slit in the shutter framed each picture. So here we have the slit principle plus the shutter principle, necessary when projected light is introduced.

The projector of Uchatius could not have been very successful or so many years would not have passed before other nineteenth-century Walt Disneys went on with it. But in the history of invention, we often find such lapses. One reason is that rapid advance in the development of one invention is held up because other technologies have lagged behind. The airplane, for instance, could not evolve from the glider until combined lightness and power could be developed in the internal combustion engine. In the same way, motion picture progress in the mid-nineteenth century had to wait for new inventions in photography and lighting and did not get into full stride until thin, flexible celluloid went into production.

The question may be asked here: what had photography to do with the work of Walt Disneys like Uchatius? The fact is that it had a close connection with any representation of motion. Before instantaneous photography, no one knew exactly what motion looked like. Drawings of a galloping horse, for instance, were based on pure guesses. These guesses, we now know, were false. Old hunting prints show horses in positions which they could not conceivably take. So when the Walt Disneys of the slow-photography days analyzed a rapid movement into its small parts, as they had to do to produce their sequences, and then put the parts together again in their machines, the movement was not true or lifelike or convincing. A person accustomed to seeing a horse run might not spot what was wrong in a still drawing because his eye was not quick enough to catch that particular moment, but when the whole run was reproduced—a thing which his eye had seen and of which his mind had an impression—he was sure to sense the errors that had gone into its construction.

5

By 1861, photography, though still far from instantaneous practice, was producing good still, posed pictures. A Philadelphian, Coleman Sellers, who had followed the development of animated cartoons, conceived the idea of making a series of posed photographs in a motion sequence. His difficulties may be imagined if we try to hold some attitude we have struck in walking or running. His studio, with its actors holding a raised foot or arm in a fixed position while Sellers covered his head with a black cloth and shifted his glass plates, must have had a comic look. He arranged his shots round a paddle wheel which he turned, and the result was probably as false an illusion as any achieved by the animated cartoonists.

In the 1870's, photography began to approach its instantaneous phase. Dry plates replaced wet plates in the camera, and silver salts were made more sensitive and, finally, the shutter replaced the old cap which was removed from the lens by hand when exposure was made. As these changes came, artists, students of anatomy and optical explorers got more and more doubtful about the old conventions of representation of motion in art. Etienne Jules Marey, a French physiologist, became convinced that drawings, for instance, of a galloping horse with all four legs extended at the same time were wholly erroneous.

On the Pacific Coast, a California millionaire, Leland Stanford—whose fortune later founded the university named for him—was studying, from another point of view, the gaits of horses. Stanford owned a great racing stable and was an addict of the track. There is a story that he got into an argument with a friend—also a racing fan—who said that a horse never, at any gait, had all his feet off the ground at once. Stanford then bet his friend $25,000 that he was wrong and set about proving it. He hired an eccentric photographer, who called himself Eadweard Muybridge, to make an exhaustive study of gaits with a camera. Muybridge erected a white background behind a running track and ranged twenty-four cameras in line along the track. The shutter of each camera was made, by a trip and electromagnets, to open automatically as the horse passed before it. Thus Muybridge got pictures of a sequence of positions which not only won Stanford his bet but revolutionized the whole practice of graphic art depicting animal motion. Looking at these photographs, draftsmen trained in the old conventions could scarcely believe their eyes when they saw what strange contortions the horses got their legs and bodies into, yet no one could refute evidence furnished by the eye of the camera.

Eventually Muybridge set up these photographs on a disk machine like the others and made a sort of motion picture. But the real effect on movie history came when Marey in France saw Muybridge's photographs and was inspired by them to make what was probably the first real movie camera. This was one camera—not twenty-four. By 1889 he had perfected this, and in the Paris exhibition of that year, he showed a camera and a projector using film. While he was operating these before an excited crowd at the exhibition, he had a visitor who asked for a special demonstration and a chance to examine the apparatus carefully. The visitor was Thomas Alva Edison of West Orange, New Jersey.

But this was the great year, 1889. It was a great year for motion pictures because in it the Eastmans made real film and put it on the market: thin, tough, translucent ribbons which could be wound on spools and could move through elaborate mechanisms without breaking. But still more vital, the Kodak company had found a way to impose upon this film a sensitized photographic coating—actually another film but so extremely thin and insubstantial that it would not hold together by itself but must have the celluloid backing. The Eastmans did not make this film for moving pictures; they had made it for their little amateur cameras to replace the glass plates then in common use. But when it got into the hands of the movie experimenters it seemed to solve all the problems of making photographic moving pictures.

It is an odd but almost invariable fact that when a new thing appears it comes from several sources at the same time. Since the early nineteenth century, scientific thought and experiment has kept at nearly the same level throughout the civilized world, so several independent, separate inventors in different places are likely to get the same idea at almost the same moment. Many of them apply almost simultaneously for patents and it sometimes takes years to search through all the evidence and decide who had the idea first. It was found, for instance, that the Eastmans had not actually invented photographic film; that a patent on it had been applied for two years before (in 1887) by Hannibal Goodwin, a fact which, twenty-seven years later, cost the Eastmans about five million dollars. So, although we find that as the year 1889 came along experimenters in various places had film, it was not all Eastman film.

The tragic Augustin Le Prince had it as we have seen; Etienne Jules Marey had it in France; William Friese-Greene, a brilliant and tireless British inventor, who probably came as near really inventing the movie camera and projector as anyone except Le Prince, had it, and a form of it was used by the last of the nineteenth-century Walt Disneys in Paris, Emile Reynaud.

If we pause in our story to look at the ghost of Reynaud, it is not because his work had much effect on later movies but because he used a principle none ever seems to have used before and which vanished with him. His projection was all done with mirrors, a scheme he devised first for a popular toy, made in 1877. The toy was called the "Praxinoscope." Pictures were drawn on the inside of a cylinder. Within the cylinder was a polygon of mirrors. From above, a light shone down. As each mirror came before the eye, it reflected the picture opposite it on the interior of the cylinder. As the cylinder and polygon turned, the successive images *merged into one another*. There was no slit, no shutter, no interval of darkness.

When he came to projection, Reynaud used two "magic lanterns." One threw the *permanent scene* against which the characters were to move on the screen. The other shot light through a moving film. On this the characters, in their successive postures, were drawn. After passing through the film, the light struck the revolving polygon of mirrors which reflected the images onto the screen. The device was continuously luminous; there was no jar or flicker caused by shutting off the light.

6

In October, 1889, when Thomas Edison got back from Paris, he obtained a piece of the new Eastman film. He had been thinking for two years, off and on, about what were then called "Living Pictures," about which a good deal had been published. His invention of the phonograph had started this thinking. If he could link up his phonograph with such pictures, what a sensation it would create! He had not given much concentrated thought to it—he was immensely busy in those years—but now, with the memory of Marey's apparatus and, possibly also that of Reynaud which had been exhibited at the Paris exposition, and with a piece of photographic film in his hand far better than any he had seen, the idea came back to him with renewed force.

The phonograph, by this time, had begun to make money for its inventor in a way that seems strange to us. Many of these machines, equipped with earphones and hitched to a slot machine device, had been installed in "phonograph parlors" in the cities. A visitor to one of these establishments would stand before the machine, clap the earphones to his ears, drop a penny in the slot and listen while the needle scratched its way round the wax cylinder. The machine was a very crude, early edition of the modern juke box, but instead of playing for dancing or to enliven the atmosphere of a restaurant, it played for the enjoyment of a single individual. We must remember, however, that the people who stood enthralled before these machines did not do so from enjoyment of the music. They did it because the record of sound was a startling marvel; the thrill came because the listeners could hardly believe their ears.

Thus, when Edison began to think of moving pictures, he thought of them in terms of "parlors" and slot machines. His plan was to make a machine in which a person, after dropping a coin in the slot, could see the pictures.

From the first, Edison had thought in terms of photography, not drawings. Knowing from Muybridge as well as Marey the point at which instantaneous photography had arrived and, finally, getting the perfect device of the Eastman film, he set his laboratory staff to work, first, on a camera and a peep show.

Moving pictures were turned over to a brilliant assistant named William Kennedy Laurie Dickson. Dickson was far more enthusiastic about the idea than his chief. Edison was deeply absorbed in a machine for crushing ore, and the peep show seemed to him a mere toy with very moderate commercial possibilities. Several times the thought came to Dickson that the pictures would be far more effective if projected on a screen, but when he suggested this to Edison, the Chief refused to listen.

"This thing is a toy," he would say, in effect. "It should be made and sold as a toy. It has nothing to do with theaters."

So Dickson made the Kinetoscope. A film moved continuously before a very strong light which threw the pictures on a ground glass plate.

It should not have moved continuously. It should have had an intermittent mechanism bringing each picture to a stop for a fraction of a second before the observer. To overcome this defect, a shutter was devised which cut off the light between the pictures.

But when Edison—or Dickson—made the camera, the continuous moving film became impossible. A film must stand still to record a picture. So for the camera, called the Kinetograph, Dickson—or Edison—used the famous perforated film already patented in England by Le Prince and in France by Reynaud, and a sprocket to move it and hold it in position for the shot. Why *this same mechanism was not used in the peep show is* difficult to understand; it was not, however, and when various inventors tried to throw Edison's films on a screen, its lack became very evident.

When Edison saw the finished Kinetoscope peep show and the Kinetograph camera, he regarded them with contempt. Toys! Hardly worth the waste of valuable time! He patented them in America, but he valued them so lightly that he did not bother to patent them abroad. It was not, he said, worth the few hundred dollars it would cost. The toys would have, maybe, a temporary vogue and then be forgotten.

Even when he saw what a tremendous vogue the Kinetoscope did have, he was skeptical about its future. But he was shrewd enough to establish one rule. He would sell the Kinetoscope peep show machine to anyone who wanted it but he would not sell the Kinetograph camera to anyone. He would make *all* the films himself and force Kinetoscope owners to buy them from him. So when the demand came, he set up the first American film studio called the Black Maria—a queer device which rotated to follow the sun, as instantaneous pictures could not be made by artificial light—and staged there some of the most absurd nonsense a serious, adult man has ever engaged in. One film, for instance, consisted entirely of a man sneezing. This was put on by one of Edison's employees, Fred Ott, who, when he was not working, had a number of parlor tricks. The Museum of Modern Art in New York still has some of the early Edison films and shows them, from time to time, to members of later generations who are amazed at the childish performances with which the American screen art began its career.

The first sensation produced by the Kinetoscope was, of course, the same as that of the slot machine phonograph. The little pictures were magic. They were looked at by thousands of people from sheer curiosity, not in any search for entertainment from the subject matter. The fifty-foot films, with their sixteen photographs to the foot, which lasted about a quarter of a minute, told no story, pointed no moral. All that was necessary was that they should move. Spectators rushed out to tell their friends that they had seen pictures move; the friends refused to believe it until they had gone to see for themselves.

It was obvious to the Edison people that this thrill would soon wear off; visitors to the "parlors" would soon insist on something more solid in the way of entertainment for their nickel. So, in the Black Maria, famous dancers and boxers were hired to perform before the Kinetograph.

At the same time it became obvious to those who understood showmanship, that any show which could be seen by only one observer at a time, especially when he was obliged to stand through it in a cramped, uncomfortable position, could never become a permanent success. Fully half the enjoyment of watching any spectacle comes from sharing it with others. It is the chorus of laughter from the audience; it is the audience's tense silence in a mysterious or tragic sequence that completes the success of a dramatic performance.

This was quickly realized when the Kinetoscope reached Europe. In such cities as Paris and London in the 1890's, people in general had a more mature attitude toward entertainment than in, say, New York or Chicago. In Paris, the thrill of seeing pictures move had been worn off by the beautiful, luminous animation of Emile Reynaud's *Théâtre Optique* which had run for two years before crowded houses in the Musée Grevin before the Kinetoscope arrived.

When it did arrive, not being patented in Europe, it was fair game for every experimenter. It was studied, taken apart and instantly initiated with improvements. Robert Paul, a London instrument maker, built sixty Kinetoscopes the year after the first Edison machine arrived there. When Edison discovered this, he refused to sell his films to Paul, so Paul made his own camera and took sequences—including news reels—which were far more interesting than Edison's. With a Kinetoscope to guide him, any intelligent mechanic could construct a camera, and thousands of cameras would have been built in the United States had not Edison's American patent interfered. Within a year also, Paul had begun work on a screen projector in which he corrected Edison's fault and provided for intermittent movement of the film.

The same things were done in France by the Lumière brothers.

Their work attracted the attention of Georges Méliès, a magician, who was the first to see the possibilities of the film as an art medium, and who invented the screen play. Of all the ghosts in the history of motion pictures, Méliès has had the most credit—every historian of the screen has paid him tribute as the father of the modern cinematographic art, until, at last, he is no longer a ghost but a substantial historical figure. But Méliès was not an inventor in the technological sense. Thus, in Europe, the history of the cinema moved far more rapidly toward its ideal of today than in America. Several writers of motion picture history believe that, but for the interruption of the World War in 1914, when the American industry was able to surge ahead, Europe would have gained a lead in motion picture production which could never have been overcome. There is one factor, explained in another chapter, which leaves this belief open to doubt: the peculiar American genius in mass production.

7

Americans were not idle in 1895 and 1896 while these things were happening in Europe. They were simply less free to act. No one but Edison could make a camera and therefore no one but Edison could make pictures. And as Edison and his assistants—despite their inventive genius—had exceedingly crude and childish conceptions of dramatic entertainment, they went on producing atrocities and no one could do anything about it.

On the other hand, Americans could do something about projection on a screen, as Edison had never patented a screen projector. The first American public commercial showing of screen pictures was put on in New York City by Woodville

Latham, May 20, 1895. It made a sensation, and established a tremendous American demand for projected motion pictures. Technically, however, Latham's projector was not a success because it contained Edison's mistake of the continuously moving film. This fault was compensated for in the peep show Kinetoscope but, in projection, no light could be found powerful enough to overcome it.

Independently, while Latham was failing, an ingenious inventor named Thomas Armat was finding the answer. Armat saw as several European inventors had seen—that each picture must be held at rest for an instant before the lens. To accomplish this, he worked out a cam and gear wheel device. At intervals on the gear wheel, teeth were ground off. As the wheel revolved and the cam reached a smooth part of it, the film would stop, starting again when it encountered the next teeth.

When the Edison people discovered that Armat had patented his projector, they advised Edison to worry about it. It was true that Armat had used Edison's sprocket wheels and perforated film and had produced intermittent movement by a device similar to that in Edison's camera, but the fact that he had used these things for a *projector,* not for a peep show or camera, made Armat's patent valid. So the Edison people held a series of conversations with this inventor.

They told him that he could never finance this invention. His name was wholly unknown. No one with an unknown name could get capital enough to put over anything as novel as screen moving pictures. In any case, he would have to use Edison films. On the other hand, the Edison name had tremendous publicity value. Since the "miracles" of the incandescent lamp and the phonograph, the public had come to believe that anything with the Edison name attached to it must be a "miracle," or at least a sound, practical invention. Why not, then, sell Edison his patent?

Because these things were true in 1896—for reasons the next chapter will explain—the Edison interests were able to make a ghost of Thomas Armat. They persuaded him to sell his patent and, as additional compensation, gave him a job in the West Orange laboratory where he promptly disappeared from public view. They then launched his machine in a garishly built-up New York show as "The Edison Vitascope." With this show, the American Motion Picture Industry was born.

On its face this looks like an ugly story. Yet there was nothing illegal about it and it is perfectly possible that Armat, by himself, would have had trouble financing his project. The invention might have been stolen outright and Armat might have been unable to bear the cost of fighting the infringer. This has happened to other inventors. These at least were the arguments advanced by great promoters like Edison. American business had become ruthless enough by the 1890's. Its history after the mid-century was full of blacker pages than this, as we shall see.

But would it not have been possible for Edison to have used Armat's name—calling the new device, for instance, "The Edison-Armat Vitascope"? Such a suggestion would probably not have appealed to the laboratory executives. The patent, bought and paid for, belonged to Edison and he had a right to do what he liked with it. For publicity purposes, any other name hitched to Edison's would, they believed, be harmful.

The Vitascope was an immediate and immense success. The public gave Edison full credit. It was just one more marvel, one more feat of wizardry. And even today, a large part of the public gives Edison credit for inventing the whole of the movies from scratch.

With the success of Vitascope, Edison began to take motion pictures seriously. When imitations came, he watched them carefully. When great quantities of foreign film, containing the fine productions of Méliès and others, arrived in this country and were enthusiastically run by the owners of Edison projectors, he saw danger to the monopoly of the Black Maria, and his lawyers investigated ways of keeping out the imported films. Finally he made concerted and costly war on all "enemies." He employed private detectives to scour the cities looking for illegal machines. Importers of foreign films were prosecuted as smugglers. After all the films were perforated, they had been made by imitations of Edison's patent; they could not be used in the United States.

Finally, however, the legal business got so complex, suits were so constant, took up so much time and delayed the industry to such an extent that Edison made a compromise. Every company which seemed to have a legitimate patent for an improvement of the Vitascope was invited to join a combine called the Motion Picture Patents Company. In this all patents would be pooled and all members would pay a royalty to Edison —because, his lawyers said, no complete machine could be made without using an Edison patent in some part of its mechanism. Only the members of the combine were to be permitted to make machines or films, and the combine would unitedly

Columbia's Technicolor Production "The Swordsman"

IN A MODERN STUDIO

It is a far cry from Edison's "Black Maria" to the studio of Columbia Technicolor in which this scene from The Swordsman *is being shot. Yet only fifty years have passed between them—years of constant, patient invention by an army of unknown experimenters in light, sound and photography.*

Warner Brothers Pictures

STUDIO TECHNIQUE

This photograph of the "shooting" of Meet John Doe *shows how far the Warner Brothers have carried studio technique. The camera boom, the overhead lighting, the artificial rain are products of years of constant ingenuity.*

prosecute all outsiders. Combines were not a new idea. The most famous one before this was the sewing machine "combination." Edison's combine lasted until 1917, when a decision by the United States Supreme Court dissolved it.

8

Thus the great motion picture industry became standardized in America. By 1917, it had reached such large proportions that it was impossible to change much of its basic technique. Film producers, machine manufacturers had tooled their plants to certain specifications. Width of film, number of pictures or "frames" per foot, timing, spacing, everything was based on Edison-controlled patents—actually, for the most part, on the patents for the old original peep show. Technicians say that many of these things were wrong. They say for instance that larger pictures such as those of the vanished Le Prince would have given far better results. It made no difference. The formulas for the whole production had been crystallized and it would be too expensive, too disrupting to change them.

More important for the social effects of the movies, film production had also followed, to a great extent, the Black Maria pattern. For years, slapstick, custard-pie-throwing humor dominated motion picture comedy. The idea of the chase, begun in Edison's early picture *The Great Train Robbery,* was done to death. There were exceptions, of course, in great productions like *The Birth of a Nation* and *The Covered Wagon,* and Charles Chaplin often raised the comedy above the juvenile level. But the general tone of the movies was so low that by 1926, the whole American industry had come very close to going on the rocks. It was saved then by the introduction of sound.

You may ask, at this point, why pictures in Europe, independent of the Edison influence, did not break all this tradition. The answer is that they broke much of it for a number of years. There was far more artistry, for instance, in European film production. But Europe, since the 1890's, has always moved more slowly than America in industries which require huge quantities of material and vast capital. In 1914, England, France and Germany were well ahead of the United States in quality, and they had amassed considerable capital behind the motion picture industry. Then, for four years, the industry in Europe was virtually stopped by the first World War, while in the United States it went into mass production. As we have seen in the chapter "Behind Ford," America led the world in every sort of mass production. With unlimited capital, the American motion picture industry grew, between 1914 and 1918, into a giant. When Europe emerged from the war with its capital gone, it was easier to buy American machines and American films than to make enough of their own to satisfy the popular demand. And to those Europeans who were not looking for "art" the American pictures were satisfying enough.

All the same, in the postwar years, some of the greatest silent films ever produced were made in Europe. Some of them, like *The Last Laugh* with Emil Jannings, aroused American critics to protest against our American pictures. Finally even the public protested and, for a time, in the early twenties, many theaters failed and in others the audiences were so thin that their owners could hardly make a profit. There were, of course, other factors working against the movies. One was the thrilling new device of radio which kept millions of young amateurs at home experimenting with its fascinating technique. Another was the increased popularity of the automobile. With these attractions, the monotonous, dreary, sugary and sentimental nonsense which poured out of Hollywood could not compete.

Just at this crisis—and only just in time—came the sound film. It seems curious today, when you see one of the old silent films shown occasionally at the New York Museum of Modern Art, how so large a public could have endured the old pantomime so long. The technique of sound-on-film is, of course, one of the most fascinating stories in the history of invention. Inventors had been reaching for the synchronization of sound and pictures ever since Edison had dreamed of combining them in slot machines. But the perfection of it had to wait for much invention to be done in other fields—notably radio, from which came amplification and the "wiring for sound" of the theaters. Other scientific research had produced the photoelectric cell, an invention which came to America from Germany through the war.

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The use of sound revolutionized the movies, gave them new life and greatly raised their artistic level. Studios, theaters, projectors, cameras, everything had to be overhauled, much of it made new from scratch. Production, directing, casting, acting and writing went into new phases. Actors who had performed beautifully in pantomime were found to be inadequate in speaking parts. Other actors, whose work had been confined to the stage, got immediate jobs in the movies. More scenarios were taken from plays than from books. Much beautiful stage technique, developed through centuries, could be adapted to the new pictures. Whole new sound-effect arts were developed. Many "location" productions were found impossible and the whole business was confined more and more to studios with selective acoustics.

It was all a very healthy house cleaning. Many of the Edison cobwebs could be swept away, although in the first talking pictures his phonograph played a part. On the technical side, America got in on the ground floor, though sound-on-film was actually achieved by Eugene Augustin Lauste in France. But it was the American chain of inventions—telephone, microphone, audion tube, amplifier—plus the American surge ahead in the art of radiotelephony that made the final sound synchronization possible. Adding to these things the mass production tradition, the Hollywood establishment and the long experience in handling and distribution of film, the United States was able to keep the lead.

With sound came an immense improvement of American pictures on the artistic level. There is, of course, abundant room for more. There is still much blindness in Hollywood about "what the public wants," as the success of many foreign pictures has shown. But there can be little doubt that the cinema throughout the world has become a genuine art form as well as a powerful educational and propaganda medium. In the second World War, it became a valuable adjunct to aviation when films were used for the briefing of transport pilots and for an accurate record of bombing and combat operations.

10

But the meaning of our story here has been given by the armies of forgotten men in screen history. It is not the work of any one genius or any one laboratory which has made this thing such an important part of our lives and such a vital force in the world. It is a summation of all the midnight hours, the agonizing, discouraging days of men like Le Prince, Friese-Greene, Reynaud, Armat, Muybridge, Marey and a thousand others; their failures, their little momentary successes, their struggles against greed and cynicism and the contempt or indifference of their fellow men. And it reaches out, too, into the little circles of light in a hundred other kinds of laboratories where Benjamin Franklin and Michael Faraday, Galvani, Volta, Ampère sweated over their condensers, their wires and their little sparks; the upstairs room where Bell heard the first faint sound of the human voice through the head of a miniature drum; the attics and cellars and shops where Hertz, Maxwell, Marconi felt invisible waves; the room where Edwin Howard Armstrong handled his tubes and circuits, the corners where Daguerre and Niepce found the silver salts that recorded light—all these places and so many others that it would be impossible to find them all. But turn out one of these lights and the whole structure falls; it is only because they all burned when they did that we can go down the street tonight for an hour of color, sound, romance and dreams, or to watch the world's events of a few days past in quick exciting imagery.

These men become ghosts, after all, only when they are forgotten.

8

BEFORE AND AFTER EDISON

I

ON A SLOW LITTLE TRAIN THAT MOVED WITH MUCH SMOKE and noise in eastern Michigan between Port Huron and Detroit, passengers turned to look at the boy who passed down the aisles selling papers and candy. Strangers noticed the abnormal size of his head. Was he deformed, an imbecile? If they stopped him to buy, or to satisfy their curiosity, they were startled by his eyes. His eyes were so intense, so mature, indeed, over the childish nose, the broad, grinning mouth, the enormous expanse of chin and jaw that they seemed misfits in the boy's face. But they were not an idiot's eyes and strangers asked questions of the conductor or the habitual travelers of the line.

"No. There's nothing wrong with Tommy, unless he's too smart. He can't stick in school, but there's other ways of being smart."

School was a casual affair in Michigan in 1859. If a boy went into business at twelve he was likely to learn more about arithmetic, for instance, than he would learn from a blackboard. In a free-for-all land like the young state of Michigan, where everyone was out on his own, earning money, saving capital for some vast dream of enterprise, schoolboys were easily bored by theoretical figures in books. But handling the realities of merchandise and hard silver dollars, touching profit with hands callused by the earning, arithmetic came quickly.

The conductor of the Detroit-Port Huron train understood the smartness of twelve-year-old Tom Edison. In the car ahead, half-baggage, half-smoking, it was evident enough. Beside the pile of his newspapers, magazines, candy, which Tom kept in the baggage compartment, was a pile of fruit and vegetables. At a certain way station a wagon would be drawn up, driven by another boy—an Edison employee, and from it more fruit and vegetables would be added to the pile. At Detroit, the pile would be unloaded and sold, other young employees assisting. The conductor knew all this; knew that a business of considerable size was being carried on in and through this train and knew further that it was his duty to report it to the railroad company for freight charges. But it was an easygoing time and the conductor was easygoing too and, possibly, found watching Tom Edison at work a fascinating occupation during an otherwise dull trip.

After passengers had seen Edison in operation for a year or more, bought his goods and overpaid him, they began to guess that he was growing rich. The conductor knew better. He knew that Edison was not poor—had never been poor, being the son of a prosperous father—but he knew, too, where the business profits went. In the close, ill-smelling smoking compartment of the baggage car, rarely used by passengers because of its discomfort, was a well-stocked chemical laboratory. There was chemical apparatus built in a small Detroit shop by a mechanic named Pullman during the moments when Pullman was not building experimental sleeping cars. There were rows of bottles—some of them containing rare and expensive compounds—uniformly labeled "Poison." Here went most of Tom's profits. Here, too, was spent a considerable part of the time offered by the slow trip—at least until the day when an unforeseen reaction caused by the mingling of some not wholly understood chemicals set fire to the car. When that occurred, the long-suffering conductor threw the whole affair out of the train, not realizing at the moment the extent to which he was arresting the education of a youth whose name would one day be blazoned across the world as the world's number one genius of invention.

What was left of Tom Edison's profits after the purchase of chemicals went back into the business. He understood the outlay of capital to make two dollars where there was only one before. He understood charging outrageous prices when the traffic would bear them, drawing in his horns when supply exceeded demand, getting the jump on competitors, paying his labor precisely what it was worth. And he was rarely, if ever, held back in these practices by ethical considerations. What he did not understand, oddly enough, was personal wealth. He spent as little as possible on his clothes, food or comfort and never dreamed of being rich. Play, sport, idleness, were completely outside his comprehension. Rest and especially sleep were, for him, intolerable wastes of time. Even in his childhood and adolescence, long hours of which are spent by most people in bed, Edison would turn sleep on and off as if he had turned a switch

—ten, fifteen minutes at a time, day or night—and the blackness of midnight or the gray of dawn were as familiar to him as the sunlight of high noon.

When the sweating, sooty train pulled in at Detroit, belching its wood smoke from a funnel stack, Tom Edison had nine free hours ahead of him before the train started back. He went at once to the Detroit library. There he would read all day except for the time it took to transact his business—buy, sell and boss. His reading was mainly in chemistry, the great passion of his life. Edison has been held up as an example to many millions of dreamy or wandering schoolboys for his power of concentration. Men who knew him later, however, learned that he had this in double force, a fact which is not explained to schoolboys for fear of disastrous consequences. He was probably one of the few men who ever lived who could keep two parallel trains of thought running in his mind at the same time. Thus he could switch from chemistry to the newspaper business, for instance —a long jump—instantaneously, and switch back again with no damage to either. Perhaps this was a gift inherited from some remote combination of ancestors. Perhaps it was possible because this boy and man automatically shut out all the things which make up the fine mosaic of other great men's thought: love, friendship, surprise, beauty, humor and conscience; pity, sympathy, dreams and play, the enjoyment of the warm, good things of life. When Edison met these things, they confused him, so he learned early to shut the door on them and, as far as possible, to keep it shut. This left his mind free for the flow of those currents in which he was intensely interested, left it so undistracted by others that he could keep two flowing at once.

2

The Civil War came when Edison was fourteen. The war did not trouble him. On the contrary, it presented him with a new source of profit. His background was not precisely patriotic, so he was not repelled by the thought of profiteering. His grandfather had fought with the British in the Revolution and his father was a Canadian citizen. Tom conceived the brilliant idea of using Morse's magnetic telegraph to sell papers along his route. News of the war was in great demand. In Detroit, the newspaper offices displayed the headline news on a bulletin board before the papers themselves were printed. But along the rail line to Port Huron, people had to wait for the papers. It occurred to Edison that if he could get the headlines to the little towns ahead of him, there would be a great demand for his papers. He therefore wheedled and bribed the Detroit operator into telegraphing these headlines to the operators in the stations along the line. He knew how quickly gossip would spread in a small Michigan town.

When the train drew into each station, Edison would make a quick estimate of the crowd waiting for his papers and raise the price to from ten to twenty-five cents for a three-cent newspaper.

"I decided," remarked Edison at fourteen, "that the telegraph was a great invention." It was great to him, at first, because it made money for him, but presently it began to fascinate him on its own account. He soon grasped its technique. He made a set of instruments of his own and set up an experimental line. Finally it absorbed him so that he decided he must live with it, spend all his time with it. So he learned telegraphy.

Operators were in great demand in the war years because of the shortage caused by army needs. Thus Edison, once he learned the code, was always able to find a job. This was fortunate because he was usually fired after a few weeks when the routine work of filing, sending and receiving dull telegrams began to bore him. Then messages would accumulate and be forgotten while he read his chemistry books, or experimented with the instruments. His first invention was designed to protect him in these pursuits. During the night, operators were required to send in signals at certain hours to show that they were awake. Edison rigged a device hitched to a clock which sent the signals automatically at the proper times, so that he need not be interrupted in his reading or, if the moment came during one of his snatched intervals of sleep, he need not worry.

But because the technical side of telegraphy so absorbed him, he could not bring himself to quit the work. Also, having given up his other businesses and left home in pursuit of it, he had to have the pay it brought him. So when he was fired, he simply moved on. The country was so big, so sparsely populated, and its communications so slow and haphazard that by traveling a few miles he could find himself among people who had never heard of him. In our time this would be impossible. Today, instantaneous warnings would be flashed to every office in the country to watch out for a young man with a large head and piercing eyes who might apply for a job. But in the pioneer west of the 1860's, everyone was a stranger and an equal; there was work for them all and each had a chance to assert and expand his own individuality as ruggedly, as independently as he wished. So

Edison, wandering over the face of the adolescent nation, constantly meeting other persistent, stubborn, restless, free individuals, lived a full, exciting life and learned much. The difference between him and the others, however, was that Edison was never distracted by the variety of experience; his mind automatically sorted out the material that was useful to him, to his future career, to his final success and discarded the rest.

3

This brings us to the point of this chapter, which is not merely the story of Edison's life but rather the story of a change in America; the story of how all work and effort from being separate, free, individual, disjointed, became organized and coordinated until finally, the team replaced the lone wolf in almost every department of life and work including technological invention. Perhaps the most curious aspect of the whole story is Edison's part in this change. For, after his wandering career as one of the most rugged individuals in the history of invention, he became the pioneer of its collectivization; the first American to apply teamwork to a pursuit which, above all others, was traditionally the property of lonely investigators living in garrets and carrying on their researches by the light of a candle shining dimly through cobwebs.

It may have been dissatisfaction with his roving life which implanted Edison's desire to work in a fixed place with other men. It may have been a memory of his early business career which taught him that no profitable enterprise of any size can be carried on without competent, paid assistance, and certainly his memory of the thrill of profit, investment and new profit—

not for its own sake, but to make his business bigger and bigger —had never left him. And moving about over the enormous empty land with its infinite opportunity had made him think in large terms so that his ambition would never stop short of the widest possible accomplishment.

It is certain, however, that his reading in the sciences had convinced him that technology was becoming far too complex for a single mind to apply it to any but the simplest inventions. He knew in his own case, for instance, that mathematics would always be beyond him. He understood how necessary it was, but he was incapable of learning its theory or its detail. So the thought came to him: Why bother; *if I can make money enough, I can always hire a mathematician to do the jobs for me.* The same thought—applied to experts in physics, chemistry, metallurgy, acoustics; artisans in wood and metal working —was the basis of his invention method.

4

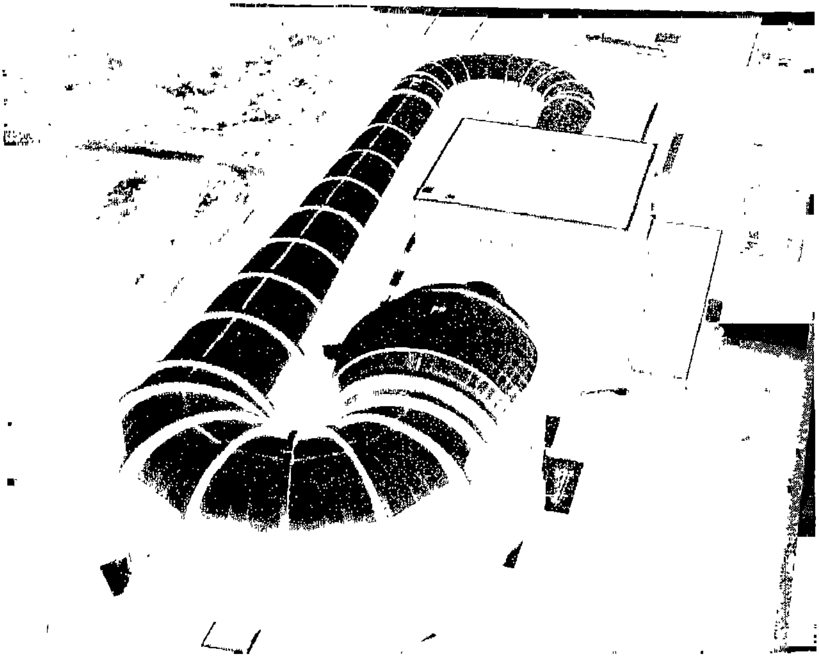
At twenty-two, however, when Edison came to the end of his wanderings in New York City, where he was without friends or money, all these ambitions were still in process of formation in his mind. Yet in spite of his haphazard work on the frontiers of civilization, his mind had greatly matured and he had carved out for himself definite grooves of thought. In almost every job he had had, he had worked without interest in the routine of telegraph operation. The news, the messages he sent, the time schedules and office hours had bored him. But the techniques of electrical communication were a compelling passion. His big moments came, not when everything was running smoothly, but when something went wrong. When storms disrupted connections, he worked with speed and ingenuity to restore them. When, on one occasion, a drunken operator, angry at his boss, wrecked a telegraph room, tearing the switchboard from the wall and throwing the wet batteries of the period on the floor, Edison rigged a makeshift system so quickly that service was scarcely interrupted. He was impatient with delays caused by technical failure or inadequate equipment, and spent hours of the time a normal, "good" operator would have put in keeping up with messages, thinking out ways to send two or four messages at the same time over the same wire.

This work made up his early training for the profession of inventor. It was not the kind of education a modern inventor acquires. Today we begin with theory. In his school an engineer studies the sciences until he understands the sure, inviolable natural laws. By evolving mathematical formulas, plotting graphs, solving equations, he knows ahead of time what will happen when stresses are balanced, gases expanded, chemical compounds combined, atoms added to or subtracted from an organic molecule, or a current induced in an electromagnet. An aviation engineer, for instance, without flying experience, can draw a picture of the air drag on an aircraft moving at supersonic speed. It is true that even a modern engineer or scientist is sometimes upset by the discovery of a new law or an unexpected phenomenon such as the neutron, but in general his approach is by way of scientific law, not hit or miss experiment. If a new condition prevents the operation of a law, he may be surprised, but he has worked his way into that upsetting moment by means of all the knowledge available to him, not by guesswork. Therefore, after his surprise, he can go back, step by step, until he comes to the point at which he miscalculated the new condition. The science of aviation, for instance, grew up following tables of air resistance proved in wind tunnel experiments with scale models. Then, in the air one day, a pilot crashed simply because of an increase in speed. In a new condition, the old laws no longer operated, though up to that particular rate of speed they had functioned in an orderly process. So the engineers went back to their tables and tunnels, plotted, worked out formulas and were able to alter design and other factors to meet the new law which began to operate when a certain rate of speed was passed. But it would have been an expensive business if they had had to crash plane after plane, pilot after pilot, until they had guessed at an aircraft which would stay in the air under the new condition.

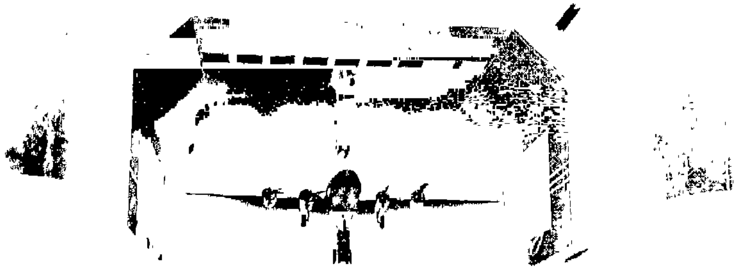
This way of invention and discovery was practiced long before Edison, and was known as the scientific method as opposed to the trial and error or experimental method. The Greek philosopher Aristotle used it before the Christian era and came to several wrong conclusions because the knowledge available to him was limited. In America, Joseph Henry, one of the heroes of the telegraph, used it. He learned the laws first, absorbed everything that had been discovered; thus he did not waste time trying experiments which had been tried before and proved impossible. Morse, on the other hand, was a trial and error inventor; he knew nothing of scientific law, learned it only by terrific effort trying first one thing, then another, until his devices worked.

We cannot condemn or discredit these guessers in the history of invention. Many great inventors were too poor or too isolated to acquire the education necessary to the scientific method. Others seemed to have a kind of intuitive genius which made it possible to by-pass much scientific education. The greatest inventor in the history of radiotelephony, Edward Howard Armstrong, who is responsible for the regenerative circuit, the superheterodyne and FM broadcasting, believes that too much scientific schooling—especially mathematics—may hinder an inventor. There must, he says, be constant experiment, demonstration with actual apparatus. Armstrong once gave a demonstration of frequency modulation in the presence of a scholar who had just written a mathematical thesis proving it to be impossible. The mathematician rushed home, went back over his formulas and equations, found a wrong premise and rewrote his thesis proving that it was possible after all, a fact to which his ears had already attested. However, Armstrong knows more, subconsciously, about natural laws than he perhaps realizes. A mind like his can jump over steps which most scientific inventors have to work out laboriously in calculus or other mathematical process.

Edison, however, was a notable example of the experimental inventor. He had no schooling whatever. This was not because he could not afford it or because there was no school; on the contrary, his parents tried their best to induce him to get at least a primary education. He was simply impatient of it; he was looking always for results, for tangible rewards. He did, to be sure, a great deal of unguided, independent reading in his early years in subjects like chemistry which fascinated him and which he accompanied by endless practical experiment, but his



Acme Photo



Owen

SUPERSONIC SPEED

This gigantic, caterpillar-like wind-tunnel is a laboratory for aviation research at Moffett Field, California. It is used for studying problems of flight at speeds of sound—720 miles per hour, and greater. When aircraft reached or exceeded this speed, a set of wholly new and unexpected conditions arose. The model plane in the tunnel does not move but wind is blown against it at the required speed.

Acme Photo

A "HOT" LABORATORY

From such closely guarded danger spots in the Oak Ridge plant the parts of the atomic bomb moved into final assembly. The photograph shows Paul Shallert, working with long tongs, dropping the "active" materials through the roof of a heavy concrete-walled cubicle for chemical processing.

reading, like everything else, was directed toward some immediate object and not used for a thorough, co-ordinated scientific grounding.

The lack of this basic knowledge was responsible for an amount of work which would have killed or discouraged an ordinary man at an early age. One illustration of this came during a series of experiments in England on automatic telegraphy for submarine cables. To try out his device, which had a recording receiver, he used twenty-two hundred miles of cable which were stored under water in tanks. "I sent," he says in his own account, "a single dot which should have been recorded upon my automatic paper by a mark about one thirty-second of an inch long. Instead of that it was twenty-seven feet long! . . . What I did not know at the time was that a coiled cable, owing to induction, was infinitely worse than when laid out straight . . . but no one told me this." Yet this phenomenon had been discovered by Joseph Henry forty years before and independently rediscovered by Faraday somewhat later and was in the books which Edison should have studied. Another case of this ignorance, which involved others besides himself, came during his incandescent lamp investigations which we shall presently discuss.

But it was this capacity for tireless effort combined with the kind of experience he had made for himself which, in his twenty-third year, pulled him out of his extreme poverty in New York and set him on his sure road to success. His first day in the city, he begged sleeping space in the battery room of the Laws Gold Indicator Company while he looked for a job. The "gold indicator" was the beginning of the stock ticker. Sleep was not one of Edison's favored pastimes. It was certain that in any place where he was supposed to sleep, he would quickly find something else to do. He had not been ten minutes in the battery room before he was studying the circuits, following where the wires led. He then studied the indicator instrument until he understood the whole system and saw the possibilities for its improvement. It was not wholly new to him as he had rigged a similar affair of his own in Boston and had tried to get it adopted commercially. But Boston was not New York. Now he was in the country's financial center. American finance in 1869 was a free-for-all game, and many of the players were ruthless and cynical speculators for whom there were no rules. At the moment when Edison arrived, the loaded dice were held by the notorious bandits, Jay Gould, James Fisk and Daniel Drew. It was their speculation which, while it ruined thousands of innocent investors and, for a time, set the whole economy of the country askew, gave Edison his lucky break.

5

Actually there was no special luck about it. Any intelligent young man could have profited by the condition of the time, and thousands of them did. It is probable that men of Edison's dynamic talent, intensity of purpose and working capacity make their own luck, by taking advantage of any situation that presents itself. But as this story is more concerned with America than it is with Edison, it is important to consider what the crisis was by which he profited, because it marked the beginning of a change in the whole picture of business, industry and invention.

The confusion which marked the era of limitless speculation was inevitable in a nation which was growing so rapidly. Before the Civil War, the territory of the United States had come to cover the full breadth of the North American continent. The war proved that it was the destiny of the United States to remain united—one nation, under one Constitution. With the Union victory, the hopes of those who had wished to split it into separate confederations of states were forever dead. Yet the actual physical job of tying together the great sprawling land, of joining the new, rich settlements in California, for instance, with the older, busy manufacturing and commercial centers of the East, was a job almost fantastic in its immensity. Between the two lay some six hundred thousand square miles of emptiness in the Great Plains, and the savage barrier of the Rocky Mountains.

By the time the war was over it was evident that this job would have to be done by railroads. No other means would be quick enough. The impulse of speed was already dominant. Inventions like the telegraph had quickened the pace of all life. Improvements in locomotives and steamboats had made everything move faster, even as far west as the Mississippi, where the big, high-funneled, paddle wheelers were racing for records. But the greatest pressure was for quick economic unity; for gold in Nevada and Colorado to provide capital for the industries in Pittsburgh and Boston; for steel and other desperately needed goods to move west; for grain and cattle to be shipped to the congested eastern cities. Once economic unity could be achieved, with the different parts of the country dependent on one another, there would be little danger of the nation falling to pieces. Railroad enterprises could and must achieve it. It was a large order, but Americans had already begun to regard the word *impossible* as obsolete.

Looking back at 1865 when the Civil War terminated, we are surprised at the state of the eastern railroads. This was not strange then, however, because they had been built by men whose minds had functioned in terms of local business, before their eyes had opened to the great vision of a continent's destiny. The railroads were owned by some fourteen hundred separate companies. Twelve different track gauges, or distances between rails, were in use, varying from four to six feet. The average length of the railroads was less than fifty miles. This meant that, after traveling short distances, passengers must change, freight must be unloaded and reloaded on other cars.

Obviously to anyone thinking about the rapid economic unification of the country from coast to coast, this situation was intolerable. Railroads must somehow be tied together, companies consolidated, track and equipment standardized.

Unfortunately, the railroad promoters who saw the nation's destiny did not all regard the vision with eyes unclouded by selfish interests. Many of them indeed, saw, instead of the picture of general national and human welfare, a picture of unlimited wealth and power for themselves. Some of them were already powerful through the kind of throat-cutting and chicanery which was so easy in that wild, free era of business when laws were lax and few had learned that social freedom depends on individual restraint.

The merging of a small railroad into a big one could be accomplished in a number of ways. The small road could be bought openly for a fair price. But if its directors were reluctant to sell or thought the offer unfair, the large road could use other tactics. It could run the small company's stock down, for instance, on an exchange where there was little orderly control. In Wall Street, rumor was a potent weapon in the 1860's. A powerful financier could spread enough destructive gossip about a railroad company in a week to frighten most of its stockholders into selling their stock, thus reducing the price at which the company could be bought. If this sort of gambling with loaded dice was unsuccessful, legislatures could be bribed into taking away the smaller road's franchise. Finally, there was the use of explosives and gunplay. All these tricks and threats, and others more devious and complex, were tried when railroad consolidation began.

The most spectacular operators in this game were Cornelius Vanderbilt of the New York Central, and Jay Gould, James Fisk and Daniel Drew of the Erie. Vanderbilt, though his transactions were highhanded and sometimes unethical by later standards, was sincerely interested in railroad consolidation and development, whereas Gould, Fisk and Drew, robbers by any standard, were really concerned only with their own fortunes. It is with Gould and Fisk that we are immediately occupied, because it was the financial frenzy they caused in the summer of 1869 which gave Edison his chance. It is necessary, however, to keep in mind the general consolidating movement which was going on in the business of the whole country, because it was this movement with which Edison later allied himself and which was responsible for the success of his method of invention.

Jay Gould and Jim Fisk, having played the railroad finance game until it had made them rich and until they had become practical dictators in Wall Street, now decided on another gamble—this time in gold. Gold was the medium of foreign exchange and necessary for imports, exports and customs, but for domestic purposes the currency was paper money which had varying values. Thus, in June, 1869, it took $130 worth of greenbacks to buy $100 worth of gold, but no one regarded this as a fixed price; gold had been higher before and it might well go higher again, in terms of paper money. Gould and Fisk conceived the brilliant scheme of making it go higher.

Their idea was to buy all the gold in the country except that held by the government. "Cornering the gold" was the current expression. Once they owned all the gold, they could put their own price on it when they decided to sell. Actually, when they got started they bought many times the amount of gold there was in existence, because many speculators sold short; that is, they sold promises to deliver at some future time, hoping the price would go down so that they could buy cheap and profit by the transaction. Naturally when the price went constantly up instead of down, these men—and there were hundreds of them—were ruined.

It was, of course, the public's inexperience in large-scale speculation, its ignorance of trickery, its gullibility for rumor due to the absence of sound communications, and the lack of controls on banks and exchanges which made the scheme possible. It is the communications aspect of it which touches Edison's story.

As gold fluctuations began under the conspiracy, the room of the New York Gold Exchange—or "Gold Room" as it was called—where the quotations were made, was far too small to hold all the interested people. Yet all these people had to know the score at every minute of the day. At the height of the frenzy in late September, prices were changing so quickly that a man who had sold his gold short at eleven o'clock might find himself ruined at twelve. The brokers' officers were scattered through the city. So were banks and large commercial houses which had been caught in the scheme. There were no telephones. Business in general was transacted by small boys running from office to office with messages.

There was, however, the Gold Indicator. This was an early form of the stock ticker and was invented by Dr. S. S. Laws who had studied under Joseph Henry at Princeton. It was still operating in 1869, though the recording ticker had also been invented by E. A. Calahan and was in use for stock as well as gold quotations in the Gold and Stock Telegraph Company, which was in competition with the Laws Gold Indicator Company. The difference between the instruments was that the indicator simply showed the figures and, therefore, had to be watched constantly whereas Calahan's ticker recorded them on a strip of paper. Both were in use in different brokers' offices throughout the city—the figures being sent out from central stations connected with the exchanges in Wall Street and appearing simultaneously on all the indicating or recording instruments.

6

Soon after Edison's arrival, he was in the Gold Indicator Company's transmitting room at a moment when the machinery suddenly stopped working and its operator went into a speechless panic. It was one of the busiest of Wall Street's days in that frantically busy summer. Within a few minutes a hundred brokers' boys stormed the office. Edison, having spent some two nights studying every minute part of the transmitter, knew at once what the trouble was and told the operator whose fright, however, had made him incapable of action. At this moment, in rushed Doctor Laws himself, "the most excited person," said Edison, "I had seen." Edison ventured to explain the trouble to Laws, though he was not an employee but merely a non-paying lodger in the basement. "Fix it! Fix it! Be quick!" shouted Laws, and Edison fixed it.

The rest of the story is like a Horatio Alger yarn. The strange looking young man with the remarkable eyes had made a sharp impression on Laws' memory. A short time afterward, he gave Edison a job as general manager, at the fabulous salary of $300 a month. In the mad days that followed, culminating on the famous "Black Friday" when the government broke the gold corner, Edison kept the indicators working. He became so impressed by the power of their rapid communication, that he decided to start a business inventing improvements. His partner was an operator, Franklin L. Pope. Edison gave out a statement to the press saying that from then on he would "devote his time to bringing out his inventions."

In 1869, this was a new idea. Invention was not a recognized profession. Inventors were solitary individuals who usually held some regular, orthodox job and invented in their spare time. Or they were poverty-stricken persons who sacrificed everything to their experiments and kept themselves alive by odd jobs picked up on the threshold of starvation and dropped as soon as possible. Usually they were regarded as eccentric, long-haired, unwashed, on the verge of lunacy and not to be trusted with money. But for a young man to set himself up in an office with a partner and a sign on the door and tell the world that he had taken on invention as a full-time business was unheard of. It is true that in his advertising he called himself and Pope "electrical engineers," but this too was a novel term and the whole affair began, presently, to interest a good many people.

Especially interested was a business executive named Marshall Lefferts, president of the Gold and Stock Telegraph Company, rival of the Laws Gold Indicator concern and promoter of the device which recorded quotations on paper instead of flashing them before the anxious eyes of the broker. Lefferts watched the progress of Pope, Edison and Company and was impressed by several of their inventions which improved and cheapened ticker service. He was so impressed, indeed, that in 1870, when Edison was twenty-three, he offered him forty thousand dollars for his patents.

The story has often been told about the odd-looking young man taking the check to the bank, of the teller having fun with him by cashing it in small bills, of how he did not know enough to deposit them and start a bank account and of his sitting on them all night lest they be stolen. Famous men enjoy telling such stories about their youth to show the innocence of early years against the background of genius and success. The fact was that Edison was already an extremely astute and hard-headed businessman, that he had already made up his mind that inventions were of value only when they were commercially profitable and that he was already firmly set in a career which would bring wealth not only to himself, but eventually to the whole world.

He was not absorbed, as so many other inventors were, in personal credit. He concentrated on the invention itself as an object of wide commercial use. Thus he had no conscience about taking another man's idea, improving it, cheapening it, getting it into large production so that it could be widely sold and widely used. If an invention was the result of an employees' thought and labor, he paid the man for his time, devised schemes for making it in large quantities and put it out as the product of his business. It was only later, when he had been played up for years as a "miraculous wizard," that his personal egotism developed and he accepted credit as sole "inventor" of things with whose origins he had had nothing to do.

With Lefferts' forty thousand dollars he added manufacturing to his invention business. He employed fifty men to make tickers. Day and night, he supervised them, drove them, indeed, at their work. He had no patience with fatigue; if men collapsed, he threw them out and got others. He was a dictator, enforced his own methods and was intolerant of suggested changes. He paid high wages and incentive pay for increased quantity of production. But he set all these scales himself, for there was no union power in those days.

Moving among his workers, guiding them, driving them did not prevent him from carrying on this independent thinking. He was inventing all the time; methods for the new so-called automatic telegraphy in which machines would grind out messages previously prepared on perforated paper ribbons; quadruplex telegraphy for sending four messages simultaneously over the same wire, the mimeograph, paraffin paper and many other new processes and simplifications.

Eventually, these far-reaching currents of his mind combined with other circumstances to induce him to abandon the ticker business. For one thing it had involved him with Jay Gould who had given him large orders and then defaulted on his payments. So Edison decided to salvage what he could from the business and put it into a real invention factory in which he could experiment, not only with telegraphy, but with every conceivable kind of device.

In 1876, then, he designed and built the establishment which will forever be connected with his name, the laboratory at Menlo Park, New Jersey. It was the beginning of collective invention.

7

It was in tune with the trend of the time. Business was following the railroads. Big companies absorbed small ones. When the railroads made their tremendous demand for rails, merging became necessary in the Kelly-Bessemer steel centers. When the railroads drew out communications, one or two telegraph companies absorbed the others and when the telephone came it followed the same design. When the fuel, petroleum, arrived, the Standard Oil Company built its power into a trust which no small enterprise could defy. Manufacturers like the McCormicks of Chicago, promoters of agricultural machinery, followed the trend. Eventually it began to look as if every industry in the country would form itself into a monopoly, cutting out all competition and fixing prices according to its own sweet will. The people, remembering its sovereignty, stopped these things when they became abuses (and it is still fighting them) and this was part of the teamwork which has resulted in the unity and strength of the United States as we know it.

All of this was a perfectly normal development as we look back at the sweep of it. You cannot have unity in a modern nation which has twelve different track gauges—or even two or three; where messages have to be relayed every few hundred miles; where a transportation company has to shop around in fifty steel factories for its rails; where you have to pay a different freight rate in every state or county; where a nut made in New York will not fit a bolt made in Chicago; where the lighting system of a city requires different voltages and cycles from that of its suburbs. If greed, piracy, murder and other destructive incidents dot the path of this history, they must be accepted with a realization that human nature is at best imperfect and that every instrument of life is as likely to fall into bad hands as good. But the measure of American success is in the fact that we remained one nation instead of falling apart into a dozen different and hostile ones; that we have kept clear of the alien doctrines of fascism and communism, preserving the free give and take among the stupendous forces of industry, government and people.

Invention was essential to the growth of the country. Each invention made a dozen or a hundred others necessary. The locomotive called for cars, the trains for track, the track for steel processes; air brakes, block signals, switching systems, thousands of other machines followed in quick succession. The telegraph and telephone required new processes for the quick drawing of wire, copper mining machinery, switchboards, relays; these new rapid communications made new speed- and quantity-printing presses necessary for newspapers—and so on; the chain is endless. Thus invention, too, had to be consolidated, speeded up, put on a full-time basis, and that was what Edison did at Menlo Park.

In that bright, halcyon time, everything seemed new, fresh, exciting. No one who watched the fabulous growth about him could have been bored for a moment. As we look back on the public of the 1870's it seems to us incredibly naive; a public composed of children, agog over every shining new object. The inventions which fell over one another as they appeared were "miracles," "marvels," "unbelievable wonders," products of "genius and wizardry." The public of 1876 refused to accept the facts of Edison's invention factory. Whatever came out of it must have been the sporadic vision of one superman, dreaming in the night. There must be one focus for their praise, one pair of penetrating eyes for their picture, one chest to pin their medals upon. All America in those astonished days worshiped individual heroes. America was great because of its great men—its Grants, its Morses, its Rockefellers, its Carnegies—not because of its millions of hard-working, team-working people who were building its structure. Today we think in terms of the Air Forces, the 88th Airborne Division, the Manhattan Project, the C.I.O., General Motors—forgetting, with a few colorful exceptions, the men who lead these groups.

Reporters stormed Menlo Park. If they were admitted they "could not believe their eyes" at the magician's performances. They paid little attention to the brilliant experts they met there, but brushed by them to the boss's door. If Edison was not too busy to see them (which was rare), they deluged him with questions about the clothes he wore, what he ate for breakfast, his opinions on religion, politics and cigarette smoking, his philosophy of life. Being extremely deaf and annoyed by interruption, it is probable that he heard few of these questions and answered them with the greatest brevity so that the reporters had to fill in the gaps to make him credible to their avid readers. A few of his commonplaces, such as his singularly inappropriate definition of genius as one per cent inspiration and ninety-nine per cent perspiration, were headlined across the country and were dinned into the ears of millions of unhappy boys who had sweated insufficiently over their homework.

Actually, Menlo Park used the brains and ingenuity of dozens of geniuses. Men, who later became leaders in bringing most of our modern world into being, were at one time or another on Edison's staff. Edward Goodrich Acheson, who spread electric lighting systems throughout Europe and later invented carborundum, was at Menlo Park. John Kreusi, who laid the technical foundation for the achievements of the General Electric Company, worked with Edison for years. A. E. Kennelly, famous for the Kennelly-Heaviside layer, a discovery which made possible effective short-wave radio transmission and which has been basic in radar development, was an Edison worker. Frank Julian Sprague, who was responsible for the electric railway, began his career at Menlo Park. William K. L. Dickson, who probably contributed more to motion picture invention than Edison did, was a devoted employee. This was the sort of man the reporters forgot and brushed by in their frantic search for the "wizard," and ignored in their stories as employees blindly following the master's orders.

Yet it would be wrong to underestimate Edison's influence. Now that the smoke of the fireworks has cleared away and the memory of their gaudy light has been dimmed by the brilliance of later technological achievement, we can see Edison for what he really was. First of all, he inspired people. No one could work with him without being on fire with ideas. His mere presence seems to have stimulated men to search their minds, bring out the best that was in them. Everything he said was suggestive. He would scribble crude sketches and hand them round. He had the kind of intuition which made him always hand the right sketches to the right man. "See what you can do with this." The very bareness, the absence of detail, made his inventors itch to fill it out. In every drawing there was the embryo of a great idea. The bigness of it as it enlarged itself in the man's imagination made him forget himself—forget everything but the thing he saw. The workers came to feel that each of them was playing a vital part in some grand strategy and there grew throughout the group the sense of *esprit de corps*, of interlocking teamwork.

And Edison did more than this for invention. He gave inventors paying jobs, provided them with the best equipment, taught them to be tireless in experiment, lifted them out of the amateur class where they had been dependent on the remote chance of finding a financier to invest, or speculate, in their work. Having done this, he offered the work of his laboratory to any industrialist who needed an invention of any kind, thus bringing industry and invention together for the first time.

8

Almost the first work of Menlo Park was for the Bell Telephone Company, established to operate the great invention of Alexander Graham Bell in 1876. It is hard to imagine the time when the human voice could not be transmitted. Yet there are people now alive who can remember that day. Even after the invention had been made, however, Bell's telephone worked only faintly and for short distances. Menlo Park gave it power through the Edison carbon transmitter.

It was experiment with this which led Edison into a wholly original invention. In the other Edison "marvels" it is difficult to separate Edison's own contribution from that of his staff and we know that some of his most famous products, like the incandescent lamp, were merely improvements upon the ingenuity of others. But the recording and reproducing of sound through the phonograph was wholly his invention. This discovery, that sound could be trapped and permanently held, is one of the greatest in all history. We have gone a long way since the little tinfoil-covered cylinder which gave back, so faintly that its deaf inventor could scarcely hear it, the reproduction of his voice. We have gone into recording on wire and into sound track on film, the accompaniment of our movies. In 1877, the phonograph was a toy, pure and simple. Its only apparent merit was that it was "wonderful." At the time, Edison saw its possibilities only as a medium of superficial entertainment. As such it had commercial possibilities and Menlo Park was set to producing it for slot machines with earphones. And it led, as we have seen, into the Kinetoscope peep show, another toy to which the inventor devoted far less thought.

The next matter to which the laboratory gave its full attention was the incandescent lamp, first invented in England in 1860 by Sir Joseph Wilson Swan. If Edison had really studied the work of Swan, he could have saved himself and his staff many sleepless nights. Swan had long ago abandoned platinum wire as the medium of his incandescence in favor of carbonized cotton thread. By exhaustive experiment, the staff at Menlo Park arrived at Swan's conclusion. Edison then decided that the cotton thread was not sufficiently substantial, so he sent his agents all over the world until he had assembled in his laboratory six thousand different vegetable fibers, each of which he carbonized by partial combustion, until he finally settled on a Chinese bamboo. The combined efforts of his workers brought this into substantial shape for commercial production and commercial use and the lamp was publicly demonstrated in 1879.

Most of the stories which have been written about Edison concentrate on the lamp itself which he merely made available, substantial and cheap. But the writers tend to ignore his really great performance in electric lighting. This was an operation called "subdivision," by means of which current could be made to light not one lamp but a whole system of lamps, each of which could be turned on and off independently of the others and by which, too, dangerous, high voltage could be tamed to the point of introducing it safely into houses for the use of ordinary people who had no understanding of its mystery. Three years after the thrilling announcement of the practical incandescent lamp, a central generating plant had been established in New York City, current moved over thirteen miles of underground wire and lighted stores and houses in many parts of the city. It was a truly great achievement and, though Edison himself took part in it even to the point of standing in the trenches to supervise the laying of the mains, it could never have been accomplished without the "invention factory" and its little army of quiet, loyal workers in full harmony and close co-ordination.

In 1887, Menlo Park became too small for Edison's extensive operations and in West Orange, New Jersey, he built the laboratory in which he was to complete his life's work.

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From this time on inventors passed more and more into the realm of ghosts. Occasionally heroic names appeared. The bright flare which illumined Marconi threw into semi-darkness the great names of Hertz, Helmholtz, Preece, Crookes, Kelvin, Lodge, Hughes, Branly and many others who had prepared the way for wireless communication. The names of Orville and Wilbur Wright have been justly honored, though the Wright brothers themselves were the first to admit the credit due Otto Lilienthal, Octave Chanute and James Montgomery for their glider experiments, and Samuel Pierpont Langley for his scientific approach to wind resistance. But for the most part, in the twentieth century, the names we know are General Electric, Bell Laboratory, Dow Chemical, Westinghouse Electric, Pratt and Whitney, Corning Glass, R.C.A., Du Pont de Nemours and thousands of others; and, in late years, the United States Army and Navy.

It is doubtless true that some of the men who work in the secluded experimental laboratories are occasionally bitter that their names are unknown; that the flashes of discovery which come to them over their test tubes and retorts are rewarded only by a steady weekly salary; that the halo which once grew round the head of a Samuel Morse (and is now the common adornment of a Bob Hope or a Frank Sinatra) can never be theirs. But, on the whole, the great interest of these men's lives is their work; ambition for the headlines never occurs to them. And they know, too, how difficult credit is to subdivide in the intricate interplay of modern scientific specializations. A man may discover, for instance, the power potential of a split atom, but a thousand others must work out as many processes before the energy *is* actually released on an effective scale. To whom can the credit go, then, for an explosion in Hiroshima or Bikini? Or, what is far more important, for the future driving of a ship or a factory by atomic kinetics, after many more thousands of men and women have brought all the thinking power of their lives to bear upon it?

It is impressive to see some of these laboratories at work. The experimental rooms of Corning Glass give a visitor the feeling, almost, of being in a cathedral—the currents of thought passing by seem so mysterious, so powerful. Here is a group concentrating on the effect of heat upon glass. As the intensity of the electrically applied heat upon a piece of Pyrex produced by some new experimental formula increases, and the visitor watches for the breaking point, every other thought leaves him. The final result may be a commonplace thing—a pie plate, perhaps—but it will spread out among countless millions of women and momentarily ease the dull jobs of their lives. But, in another room, another group is intent upon a lens for an optical instrument which may help in the discovery of a new sun or some hitherto invisible bacillus. In still another place is the testing of novel insulators, or photographic plates or bits of glass in a secret device for radar detection. Everywhere one feels the tense thinking that stretches like invisible wires across the room. The rest of the world is shut out so utterly from the visitor's mind that when he goes out of the building into a busy street, the common sights of cars and people and shops seem strange, like something known long ago and forgotten.

A few years ago, non-technical visitors to the Bell Telephone Laboratories were puzzled by the talk of men who were working on the immense problem of the coaxial conductor, which was designed to carry two hundred simultaneous messages on one wire. As the engineers tried to explain it, their language became difficult and finally impossible to follow, though it was as easy and familiar to them as any casual talk about the weather or a ball game. But eventually a point would come at which a research worker would say, "Beyond this we cannot go—the next step may take months of experiment." Today, a coaxial cable runs from Washington to New York and is used for the transmission of television.

In the research division of the Chrysler Corporation, the visitor has an easier time. In one room, a dozen eager young men test colors and lighting for visibility; in another, they put various parts of a car into machines which pound and tear at them to show how much punishment they will be able to take from the road. In the Ford plant at River Rouge, the visitor sees an instrument which measures in one operation, by means of light and photoelectric cells, an entire crankshaft to determine the accuracy of its machining without the laborious use of a micrometer. This beautiful device was developed, not by a research engineer, but by a colored mechanic who had long watched the difficult micrometer inspection and had studied the photoelectric principle in his spare time.

In the Mellon Institute at Pittsburgh, there is a modern counterpart of the Edison invention factory—with one important difference. The Institute is a non-profit organization. It is dedicated to the use of inventors or researchers in every industrial field and also to workers in pure science. The industrial part of it is managed in this way. An industry which is faced with some problem, such as the need for a high-temperature-resistant enamel, or for protecting the nutritive value of processed vegetables, "founds a fellowship." In other words it pays for a year's research on the problem to be done by an expert who is chosen by the Institute. The chosen man or woman is furnished with a private, equipped and serviced laboratory in the magnificent Institute building; he is given his own assistants and is provided by the Institute with library, machine-shop, stenographic and other services and with the aid of the permanent service staff. Besides these things, the "fellow" may attend general lectures and conferences and may gather with the other researchers in luxurious club rooms.

Walking through the corridors of Mellon Institute, a visitor may stop in some of the small rooms where these "fellows" are experimenting. He may talk with a man who is devoting a year to the improvement of a liquid designed to kill flies and mosquitoes; with another who is perfecting a fabric for unshrinkable shirts. In other white-walled rooms investigations are being carried on in plastics, coke, molasses, nickel, lubricants—a quantity and variety of enterprises which suggest the progress of technology on every level since Menlo Park and West Orange. During the war there was research in airplane materials, waterproofing of fabrics, ship paint, ration containers, shock-resistant glass, life preservers, insecticides, synthetic rubber and lubricants—things in the production of which war conditions demanded new techniques. The Institute's "pure" as opposed to "industrial" research has concerned itself with public health in matters like the control of smoke in cities, the purification of rivers and studies of antimalarial and other drugs or preventives.

The Mellon Institute, with its broad scope, its non-money-making policy and the opportunities it gives for the getting together of inventors from many industries, seems to be one answer to the criticism of industrial laboratories which are said to be too much under the domination of private corporations.

When the war came some of the industries went over more than ninety per cent to war production. Then the laboratories met new conditions. One was the necessity for speed, producing materials and machines for emergencies which developed from day to day. Another was the constant change in war needs as the enemy developed unexpected techniques in strategy and combat which had to be met in what seemed impossible shortness of time. Sometimes these changes called for the total abandonment of masses of equipment prepared after months of research. Another war condition was "security," as the War and Navy departments called it, which demanded strict secrecy throughout the plants, but especially in the laboratories. Often men working next to each other did not know what their neighbors were doing. But there was one redeeming aspect to the war work; cost, that vital factor in peacetime production, was no longer a worry. Faced with enemies who had staked everything to defeat us, our government underwrote losses from waste, change, speed, security, which would have quickly ruined any private industry. And this is one of the few progressive effects of war: the freedom to experiment and invent, unlimited by commercial controls. Out of this have come processes which would have been far too unprofitable to attempt in peacetime, but which, through their enormous use in war when cost has ceased to be an object, have actually become cheap enough for later commercial uses. If you are forced to produce an expensive thing on a large enough scale, you will often discover, by studying the process in actual operation, ways to cut the cost which would never have occurred to you in your normal planning.

The classic illustration of this last condition came with the German discovery during the first World War of the Haber-Bosch process of obtaining fixed nitrogen from the air. At the time, the nitrate source was guano, bird droppings in great deposits in Chile. From it fixed nitrogen was obtained by an old commercial process. It was known that the air contained a large amount of nitrogen, but its extraction was so difficult and expensive that it had only been done on a small, experimental scale. But when the war cut off Germany's supply of the nitrates so essential to explosives, then the nation's life was at stake and cost was forgotten. Later, however, after the experimental expense had been taken care of by the German government, it was found that the process itself could be greatly cheapened under quantity production and it has provided an ingredient for most of the world's chemical fertilizers ever since. But there are countless other illustrations in radar, electronics, plastics, refrigeration, waterproofing—a list which would use all the pages of this book.

In the research division of one of the largest airplane plants, then under war pressure, was a young engineer who had just passed his twenty-fifth birthday. The contrast between his approach to invention and Edison's was striking. The year before this lad had worked out a means of overcoming one of the worst aviation headaches of the time, a damaging wing disease called flutter. He had done this, not by flying or experimenting with scale models, but without leaving his desk, entirely by mathematics and a graph based on them so that, from that time on, flutter could be eliminated before building the plane by a simple change in wing design. Here was the scientific method actually at work; a man approached his invention with the knowledge of what had been done before and with understanding, not of the mere fact that certain forms of matter behave in certain ways under certain pressures, but of *why* they so behave. Long analysis by many students interested in "why," has accumulated this information and reduced it to mathematical formula: now it is only necessary in many cases to take these formulas, manipulate them in equations and, eventually, they will give the answer sought, before the expensive materials, machines and labor are applied.

Trial and error have not been wholly eliminated from the practice of invention. Perhaps they never will be. There are always likely to be new conditions for which no formulas have been worked out, and in some cases mistakes will be made. Mathematics itself is often deceptive. In its higher forms, only minds on the highest levels can handle it effectively and we know that even in its simpler forms we can only *approach* absolute accuracy. In deriving the formula, for example, for finding the circumference of a circle—$2\pi r$, using 3.14159 for π—we have guessed at the last figure 9 and though we work at reducing π to a decimal until we have a mile of digits, there will still be error in the result.

Incalculable advances in scientific and mathematical approach since Edison's day were necessary before work on the release of atomic energy could begin. A superficial lay observer might say that if the methods of Menlo Park had been applied to the making of the 1945 bombs, there would have been quick and horrible disaster. But, of course, those methods could not have been used, because of the millions of man hours of laboratory work which had to be devoted to theoretical analysis and the working out of new formulas and equations before any danger point could be reached. By the time it had become possible to approach nuclear fission it had become possible also to work out the controls. Also, by the time it was approached, scientific minds all over the world which were engaged on it, understood the necessity of establishing the controls before the definitive experimentation began. Chemists, physicists, engineers, by that time, had grown so forward-looking, that no step was taken until, with as much accuracy as all the world's scientific knowledge could determine, its results were predicted.

What was needed for this incalculable advance? Laboratories, universities, thousands of specialized schools, astronomical observatories; perfected equipment such as telescopes, microscopes, pneumatic pumps, instruments of weight and measure, electric furnaces, mining machinery, hydraulic devices, photoelectric cells, cameras, dynamos; all the new sciences of chemistry, electronics, metallography, spectroscopy, optics; the new communications of aviation, radiotelephony, radiophotography, radar, cinema, microfilm, printing; world-wide exploration in geology, botany, zoology, meteorology; intensive study of medicine, surgery, anatomy, physiology; but in all and above all, the infinite man hours of silent, mental searching with books, tables, sliderules and pencils scratching over uncounted reams of paper.

When the time came, under war pressure, in a climate of secrecy unapproached in all the world's history, these things were assembled. Let us remember, for a single instant, the secrecy. Secrecy is antagonistic, in itself, to scientific research. Every scientist desires and needs, first and foremost, knowledge of what every other scientist is thinking and doing. Yet the secrecy was the first condition of the Manhattan Project. Some master mind had to co-ordinate the work of four hundred thousand men, working in groups far apart so that each man must do his job knowing nothing about the grand strategy at the top and do it in such a way as to make the results fit in a precise niche among all the other jobs. Just so much work—never too much, never too little—had to be parceled out, and the records kept so that only a handful of silent men could ever see them all at once. Can we conceive of the problems of administration, of executive control, of mass-production planning, of human or personnel engineering or even of ordinary bookkeeping and filing involved in such a scheme?

Whose was the master mind? Shall we ever know? Groves, Conant, Lawrence, Doctor Smyth do not tell us. If they were forced to answer might they not say that there was no individual master—as Edison was said to be in his little Menlo Park—but a blending or interlocking of minds so perfect that a group could work as a single man? And that this group-thinking, this merging of individuals was a comparatively new thing in the world, made possible by the tightening of communications and the diffusion of knowledge and made necessary by the complexity and vastness of modern science?

It would be absurd to say that such gigantic enterprises as this can be traced to the crude organization in Menlo Park in 1876. Menlo Park was merely a symptom of the changing times; Edison was simply an alert genius who saw the change and the necessities it imposed and took advantage of it. Menlo Park is only a landmark. We can say that before Menlo Park, inventors were isolated individuals; that the strongest and luckiest individuals won out and got the credit while dozens of others, who paved their way, became unhappy ghosts. And we can say that after Menlo Park, the individuals began to drop out of the public mind—that every one became a ghost, but that most of them were happy, sharing a team's glory.

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It is often hard to prove that anything is better or worse than it was, or to predict that some future may be better or worse than today. We can only say that certain things are facts, made necessary by conditions over which no individual has control, better in some ways, worse in others in their effect on human happiness and welfare. Several modern thinkers deplore the passing of the old-time "garret" inventor. Modern laboratory methods are slower, they say, obstructed sometimes by selfish, private interests, clogged by the gimmicks of cost and profit, competition, jealousy and greed. We know that certain corporations have suppressed inventions for years in order to protect the sale of some obsolete product which has accumulated in quantity. We know that some of these inventions have been patented simply to prevent some competing company from patenting them, yet never used by the inventing corporation. We are told that because of all these abuses some industries are actually, in practice, far below the level of scientific knowledge in their fields.

An industrial research director said recently that he had great difficulty in getting temperamental young inventors to work together in harmony. Geniuses, he said, *are* usually temperamental and are often handicapped by every sort of petty jealousy and imaginary grievance; they hate rules, order, routine and regular hours.

Yet, looking over the scientific and engineering fields of the world, it seems evident that a large part of these human handicaps must have been overcome. There have been and always will be compromises; some of the great endowment groups are only too glad to sponsor individuals, give them fellowships, scholarships, equipment with which to work alone as far as they can. Such endowed institutions are independent of industrial and business pressures and can work for pure scientific and technological advance.

Unfortunately, the social inventor has not grown up to the scientific level. The science which should enable people to live together in harmony seems to be still in its amateur stage. It is, perhaps, an art rather than a science. Yet social inventors, too, must find sponsors and laboratories, schools, communication, equipment, before science moves too far ahead of them and becomes available to ignorant and destructive men.

At the time of writing this, statesmen are bickering, quarreling, advancing personal ambitions, weaving webs of jealous or greedy politics, any of which would shame the workers in a Manhattan Project. The men who produce atomic fission know, of course, that any such act could blow them and considerable portions of the world into eternity. Yet so close has science come to impinge upon society that the acts of the statesmen may have the same result in the end.

But such things are beyond the scope of this book. Our effort has been simply to understand the many forces beneath the history of invention in America; to dispel the myth of the heroes, to bring into the light the forgotten helpers and, last, to show the respect we owe to the nameless men and women who, today, by their silent, selfless, superb co-operation are making the world in which, tomorrow, we must live.